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WESTERN OREGON ANDIC SOILS

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A study was conducted to determine the mineralogy and chemical properties of "Ando-like" western Oregon soils. The samples were collected from 13 sites which formed mainly from basaltic rocks, a contact metamorphic rock, sedimentary rocks, and alluvium derived from sedimentary rock and from volcanic rock. All samples contained small amounts of dacitic glass shards. The largest amount was 1.6% on a whole-soil basis. On the basis of refractive indices and the mineralogy of phenocrypts, it was concluded that most of the dacitic glass originated from Mt. Mazama. Large percentages of other mineral grains, especially in the light fractions of soils formed from basalt, were altered and unidentifiable with the petrographic microscope. The sand-sized fractions contained 2:1 layer type clay minerals.

Amorphous materials in the separated clay fractions as determined with 0.5 $\underline{N}$ NaOH dissolution treatments ranged from 18 to 64%. Gibbsite contents in clay samples, indicated by differential thermal analysis peak heights, ranged from none to moderate (about 18%) amounts. The predominate crystalline phyllosilicate clay mineral in the samples of 10 sites was chloritic intergrade (aluminous chlorite). Montmorillinite was the major component in two soils and biotite plus vermiculite were major components in one soil. Smectite clay was present in all samples but the specific type could not be determined in the majority of the samples. Chlorite was also present in all samples. Vermiculite was present in all sites except two. Mica was absent in the clay of only one soil but it was only a minor constituent in all soils except one. A kaolin mineral was present in the clays of three sites. In all other sites the presence or absence of kaolin was not established.

All soils were strongly to very strongly acid (pH 5.3-3.8) and base saturations were low (1-30%), with 10% or less for the majority of the soils. Organic matter contents of surface horizons of soils from five sites ran over 30%. The lowest organic matter content of any surface horizon was 14%. Considerable aluminum was complexed by the humic fraction of the majority of the soils. In general, the fulvic acid content of the crude humate fraction increased with depth.

Low bulk densities of most of the surface horizons (about 0.6-0.8 g/cc) was probably due to the large amounts of organic matter.

The soils in the study have many of the same properties attributed to soils formed from volcanic ash but the mineralogy of the soils is vastly dissimilar. The soils were placed into the Inceptisol order under the U.S.D.A. Comprehensive Soil Classification System. The soils were tentatively classified as Typic Dystrandepts, Andic Cumulic Haplumbrepts, and an Andic Entic Haplumbrept.

Mineralogical and Chemical Characteristics
of Western Oregon Andic Soils

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

MINERALOGICAL AND CHEMICAL CHARACTERISTICS
OF WESTERN OREGON ANDIC SOILS

INTRODUCTION

"Ando" soils (Andosols) comprise a particular group in which

the parent material, weathering products, properties, and appearance

are usually quite distinctive. The term Ando is taken from the Jap-

anese words meaning dark soils. Certain dark-colored soils in

western Oregon have been regarded as "Andosols".

The following is a summary of the distinctive attributes of

Andosols as reported by Thorp and Smith, 1949; Fieldes, 1955; and

Wright, 1963. The Andosols have developed widely on volcanic ash

deposits and other pyroclastic parent materials in Japan, New Zea-

land, and many other places in the world. An amorphous alumino-

silicate mineral, usually called allophane, is generally formed during

the weathering of volcanic ash. Allophane, as defined by New Zea-

land workers, is an alumino-silicate gel of variable composition in

which phosphate and iron may be present in varying amounts. Allo-

phanic soils are difficult to disperse thoroughly but when this is

effected, the soils show a higher clay content than is apparent in the

field. If allowed to dry, the allophane may undergo irreversible

dehydration and result in lower clay percentages than mechanical

analyses made on wet or moist soils. The accumulation of humus

with a relatively high carbon/nitrogen ratio is abundant in the Ando-

sols. Usually the Andosol surface horizons are dark brown to black

in color, average about one-foot in thickness, have fine granular

structure, and have organic matter contents ranging up to 30% in the

darkest member of the group. Substantial amounts of aluminum are

generally complexed by fulvic and other humic acids. The divalent

base status and soil pH are commonly low but the pH is generally

higher than the base status would indicate. Exchangeable aluminum

is frequently high and free aluminum compounds are often present.

The upper horizons have a low bulk density, a high water-holding

capacity, and are mellow and friable.

Past field observations and limited laboratory analyses of the

Oregon Ando-like soils indicated a close resemblance to New Zealand

and Japanese allophanic soils. The Oregon soils have the thick,

highly organic A horizon, low bulk density, strong granular structure,

low base saturation, and low pH normally associated with the Ando-

sols. Rubbing moist soil samples between the fingers imparts a

"smeary" feeling suggestive of amorphous or allophane-like material.

Also, the presence of amorphous alumino-silicate material in two

western Oregon soils was reported by Jenne, 1961.

The Ando-like soils occur in the Coast Range of Oregon. Al-

though Oregon has a long history of volcanic activity, the presence

of significant quantities of volcanic ash west of the Willamette Valley

has been discounted by geologists. The presence of minor amounts

of volcanic ash in western Oregon soils was reported by Whittig,

et al., 1957 and Norgren, 1962. Thus, it has been generally assumed in the past that volcanic ash has not played an important role as a soil parent material in the Coast Range of Oregon. In contrast, soils formed on known ash deposits east of the Cascade Range do not have the appearance or properties of the Ando-like Coast Range soils. This left unanswered questions. Had volcanic ash deposits been overlooked in the Coast Range? Had the Ando-like soils formed from other specific parent materials? If the Ando-like soils had not formed from volcanic ash, how should they be classified?

Western Oregon has an extensive area of sedimentary rock from Eocene and later epochs which contain tuffaceous sandstone, siltstone, and claystone. However, specific studies for identifying ash or tuffaceous materials from sediments or sedimentary rock have not been made. It is also possible that the development of part of the dark-colored soils has been influenced by volcanic rock which is also extensive in western Oregon. Wright (1963) reported that soils, similar to the Andosols, formed from fine andesitic rock in New Zealand. These soils also contained considerable allophane.

This study was undertaken to study the mineralogy and chemical properties of some of the dark-colored western Oregon soils formed on varying parent materials in order to gain a better understanding of their mode of formation.

The specific objectives of the study were:

1. To chemically characterize the properties of the Ando-like soils of western Oregon.

2. To determine the mineralogy of sand and silt fractions as an indicator of parent material source.

3. To determine the amount and kind of crystalline clays and the amount and nature of the clay-sized amorphous alumino-silicate material.

4. To classify the soils according to the U.S.D.A. Comprehensive Soil Classification System.

LITERATURE REVIEW

Introduction

The dark-colored "Ando-like" soils in western Oregon occur in

Soil Region G as mapped by the Agricultural Experiment Stations of

the Western States Land-Grant Universities and Colleges (1964,

p. 38-43). The region occupies hills and mountains of the Pacific

Slope, and the western slopes of the Sierra Cascade Mountain system.

Reddish Brown Lateritic and Sols Bruns Acides are the most exten-

sive zonal soils in this region. The Ando soils occur as relatively

minor inclusions in cool, humid to perhumid parts of the region.

The Ando soils are found in association with the Sols Bruns Acides.

Some of these Ando soils were reported to be influenced by volcanic

ash in the parent material. The Ando soils have thicker and darker

A horizons, lower volume weights, and lower base saturation than

the Sols Bruns Acides. The Ando soils support shrubby and herbaceous

vegetation rather than forest but forests are encroaching on some

open areas (Agricultural Experiment Stations of the Western States

Land-Grant Universities and Colleges, 1964, p. 42).

In Classifying the soils under the Comprehensive Soil Classifi-

cation System, both the Ando and Sols Bruns Acides soils would be

placed in the Inceptisol order but in different suborders (Soil Survey

Staff, 1960). The Sols Bruns Acides would be placed in the Umbrept suborder and the Ando soils, if they contained significant amounts of volcanic ash or allophane, would be placed in the Andept suborder (Soil Survey Staff, 1960, pp. 139 and 143). In order for a soil to be classed as an Andept, tentative limits of 60% or more allophane in the clay fraction or 60% or more volcanic ash in the sand and silt fractions were set (Soil Survey Staff, 1960, p. 139).

Thus under the Comprehensive Soil Classification System the mineralogy of the sand, silt, and clay fractions are important in differentiating soil properties and in classification of the soils.

Occurrence of Ando Soils

Soils classified in the Ando group have been reported in a number of places around the world with substantial deposits of volcanic ash. New Zealand has the single largest known soil acreage developed from volcanic ash. This amount to about 13 million acres (Gibbs and Wells, 1965). The Ando soils of Japan are quite extensive (Kanno, 1961). Tan (1965) reported the widespread occurrence of Andosols over the Indonesian archipeligo. These were reported to have formed from andesitic-dacitic tuffs and lahars and basaltic-andesitic lahar. Wright (1964) reported the widespread occurrence of the Andosols along the Andes Mountains in South America. Soils classifiable as Andos occur in Hawaii (Tamura, et al., 1953). Soil developed from

ash in the much colder climate of Alaska have been classified in the

Andept suborder (Simonson and Rieger, 1967).

Occurrence and Properties of Amorphous

Alumino-Silicate Clay

The occurrence of an x-ray amorphous alumino-silicate

formed from volcanic ash has been widely reported (Birrell and

Fieldes, 1952; Aomine and Yoshinaga, 1955; Yoshinaga and Aomine,

1962; Kanno, 1959; Tan, 1964; Simonson and Rieger, 1967; Mejia,

et al., 1968; and reviewed by Kanehiro and Whittig, 1961). The term

"allophane" has been widely used to describe the amorphous alumino-

silicate mineral formed from volcanic ash and pumice.

Allophane is considered to be a "first-weathering alumino-

silicate product" in the chemical weathering of volcanic ash (Fieldes

and Swindale, 1954). Two general stages of weathering which lead

to the formation of allophane usually take place: first, hydration of

volcanic glass takes place which is then reduced to gelatinous Si and

Al (and Fe) hydrated hydroxides; and second, the hydrous oxides

recombine to form amorphous allophane (Fieldes, et al., 1954, 1955,

and 1956). These authors found enough fundamental differences in

allophane to warrant recognizing three types: Allophane "A", "B",

and "AB". Allophane B represented the first stage of its formation

when the Al and Si hydrous oxides were discrete. Allophane A formed

at a later stage when hydrous Si (isoelectric pH value about 3) was weakly crosslinked in a random fashion with hydrous Al (isoelectric pH value about 7) so that at pH values between 5 and 7 the hydrous oxides have both positive and negative sites and cohere readily. The random linking of Al and Si causes the allophane to have no crystalline structure capable of being detected by x-ray analysis. Yoshinaga and Aomine (1962) reported the occurrence of a mineral colloid formed from pumice with a more ordered structure exhibiting x-ray diffraction peaks. This colloid was given the name "imogolite".

The rather transitory nature of allophane results in a wide range in Si and Al composition, generally falling in a SiO_2/Al_2O_3 range of 0.5-2.0 (Jackson, 1965b, p. 592). Yoshinaga (1966) found a rather narrow SiO_2/Al_2O_3 range in allophanes formed in a relatively small area.

The high specific surface area exhibited by allophane (Gradwell and Birrell, 1954) results in the retention of large amounts of water. This provides a good basis for identification by differential thermal analysis as a large low temperature endothermic peak which occurs at about 100° to $180^\circ C$ (Jackson, 1956, p. 266). However, other amorphous soil colloid materials, such as finely divided SiO_2, Al_2O_3, TiO_2, Fe-oxides, and amorphous relics of weathered silicate minerals also give a sorbed-water loss low-temperature endotherm (Jackson, 1956, p. 265). Air-drying of allophanes or allophanic

soils usually produces significant irreversible dehydration which causes difficulty in dispersion of the clay for mechanical analysis (Birrell and Fieldes, 1952; Schalscha, et al., 1965). Allophane gives a stable porous structure to soils bringing about a high permeability and exhaustive leaching in humid regions and, consequently, infertility in many cases (Jackson, 1959). The high surface area and high aluminum activity of allophane brings about a rapid adsorption and fixation of phosphate (Wade, 1959). However, this reaction with phosphate is not exclusive with allophane. Phosphate and other anions are also strongly fixed or sorbed by gibbsite, kaolinitic clays, and hydrous Fe-and Al-oxides (Tammimi, et al., 1964; Tammimi, et al., 1968; and Chao, 1965).

Highly variable cation exchange capacity values have been reported for allophane (Birrell and Fieldes, 1952; Fieldes, Swindale, and Richardson, 1952; Aomine and Yoshinaga, 1955). The main reason for the cation exchange variability is the marked pH-dependency of the negative charge of allophane. Clay fractions separated in an alkaline medium showed a high exchange capacity while the clay fraction of the same soil separated in an acid medium had a cation exchange capacity about two-thirds less. This pH-dependency resulted in the development of a method for deducing soil allophane contents called "the cation-exchange delta value" (Aomine and Jackson, 1959). However, a marked pH-dependent charge is also found

for clays with hydroxy-Al interlayers, or aluminous chlorite
(McClean, et al., 1965; de Villiers and Jackson, 1967; and Chiches-
ter, 1967).

Amorphous soil minerals not forming from volcanic ash were
reported by DeMumbrum (1960) and Mitchell and Farmer (1962).

Chlorites treated with dilute acid to remove brucite interlayer
(Brydon and Ross, 1966) and interlayered smectite treated to remove
the interlayer material (Carstea, 1967) tended to become amorphous
with respect to x-ray diffraction.

Rock and Mineral Weathering and Clay Genesis

Chichester (1967) extensively reviewed the literature dealing
with the types and occurrence of crystalline phyllosilicate clays and
other minerals formed from or associated with volcanic ash and
pumice. The factors generally accepted as determining the rate and
weathering of rocks to form clay minerals are: parent material
composition, time, climate, topography, and vegetation (Jackson,
1959).

Volcanic rocks tend to form clay minerals dependent upon the
composition of their primary minerals. Rocks with alkalic feldspars
generally form clay minerals of the kaolin family under conditions of
good drainage (Kerr, 1959). Basic igneous rocks which provide a
source of Mg, Al, and Fe tend to form smectite when not in a

superhumid climate or when drainage is not excessive (Grim, 1968, p. 517-518). An example of two types of clay forming in the same environment in the same rock formation, a boulder conglomerate, was reported by Barnheisel and Rich (1967). The sodic and potassic feldspars of granitic and gneissic rock in the conglomerate weathered to kaolin minerals whereas the primary minerals of gabbro in the conglomerate weathered to montmorillinite. Under conditions of poor drainage montmorillinite may form from acid igeous rock containing considerable quantities of K and Mg as well as illite (Grim, 1968, p. 517). Montmorillinite was reported to be the initial clay in the weathering of basalts, olivine basalts, and andesites of Guam (Carroll and Hathaway, 1963). These authors reported that zeolites and glass of intermediate to mafic composition alter rapidly to clay minerals of the smectite group.

If the Mg of a basic igneous rock is removed from the parent mineral as rapidly as it is released, a kaolin mineral will be the weathering product (Grim, 1968, p. 517). Basalts in the high rainfall areas of Australia and Hawaii were reported to be weathered to kaolin minerals (Simonett and Bauleke, 1963; Ruhe, et al., 1965).

The replacement of K from primary micas produces vermiculites. In the presence of Ca or Mg, vermiculite is fairly stable but it gradually transforms into montmorillinite in the finer clay fractions (Jackson, 1965a).

Intergradient or chloritic montmorillinite and vermiculite are formed through the process of "alumination" under alternate wetting and drying and moderately drained to well-drained conditions. According to Jackson (1965a) the two chief processes which foster alumination are: (a) hydrolysis of feldspar and glass which can result in the accumulation of alumina in even rather alkaline soil horizons, and (b) protization of silicic acid of layer silicates; octohedral Al, Fe, and Mg ion liberation; and sesquioxide polymerization on negative clay surfaces.

The literature on the pedogenesis or diagenesis of clays under varying environmental conditions and in sedimentation is voluminous. Keller (1964), Lucus (1968), and Grim (1958) have produced numerous works and made extensive reviews covering these topics. No further review will be made here.

EXPERIMENTAL MATERIALS

Soil Samples

Soil samples were obtained from rather widely scattered sites in the Coast Range of Western Oregon (Figure 1). The sites were selected on the basis of the Ando-like appearance of the soils, mainly the dark-colored organic horizon, apparent low bulk density, strong granular surface structure, and a favorable drainage position. All samples were obtained on moderately sloping positions so that it could be safely assumed that the accumulation of organic matter was not due to water-logging. Only three of the sampling sites were on established soils series. All soils developed in a cool, humid climate with an average summer temperature of about 18° C and winter temperature about 1° C. Rainfall ranges about 100 to 250 cm.

The soil names by location or series, horizons, depths sampled and the field description of the apparent parent material are shown in Table 1. Morphological descriptions of most of the sample sites are given in Appendix I.

Soil Sample Handling and Preparation

The soil samples were collected during the summer period and, for the most part, the samples taken were relatively dry. Genetic

Figure 1. Approximate site location of soil samples.

    (1) Price Peak
    (2) Yaquina Head
    (3) Perpetua Head and Perpetua Beach
    (4) Hembre
    (5) Tillamook Head
    (6) Cascade Head
    (7) Mulkey
    (8) Quillayute
    (9) Camas Prairie and Camas Ridge
    (10) Molock Beach
    (11) Molock Creek

Table 1. Field description of Ando-like soils and horizons sampled.

Soil and Horizon	Depth Sampled	Parent Material	Main Present Vegetation
	cm.		
Price Peak			
A12	10-25	Volcanic	Grass,
B21	25-50	(Basalt residium)	Brackenfern
B22	50-71		
Yaquina Head			
A11	0-10	Volcanic	Grass, Wild
IIA12	10-38	(Basalt residum	Strawberry
IIAC	46-81	or colluvium	
IIC	112-132	and beach sand)	
Perpetua Head			
A12	10-43	Volcanic	Alder,
A13	44-97	(Basalt residium	Salmonberry
C	101-122	or colluvium)	
Perpetua Beach			
A12	13-25	Volcanic	Grass
B1	25-38	(Basalt colluvium and beach sand)	
Hembre*			
A1	0-10	Volcanic	Brackenfern,
A3	10-28	(Basalt residium	Alder, Vine
B21	28-43	or colluvium)	Maple
Tillamook Head			
A(CT-4)	2-15	Volcanic	Forest
A(CT-5)	2-15	(Basalt residium)	(Spruce)
Cascade Head			
A11	0-28	Volcanic	Forest
A12	30-66	(Basalt residium or colluvium)	(Spruce, Hemlock)
Mulkey*			
A11	1-25	Volcanic	Grass
A12	26-51	(Gabbro intrusive)	

*Series name

Table 1. continued

Soil and Horizon	Depth Sampled	Parent Material	Main Present Vegetation
	cm.		
Quillayute*		Alluvium	Grass
A11	0-20		
A12	21-30		
A13	31-71		
Camas Prairie		Alluvium	Grass
A	0-30		
C	31-56		
Camas Ridge		Sedimentary (Claystone or Shale)	Spruce, Alder
A11	0-30		
A12	31-69		
Molock Beach		Sedimentary (or Colluvial Sediments)	Grass
A1	6-20		
AC	25-51		
C1	91-122		
Molock Creek		Sedimentary	Hemlock regrowth, Blackberry
A1	0-30		
AC	31-61		

*Series name

horizons were sampled. When collected, the soil samples were placed in plastic bags and closed as tightly as possible to retain moisture. This precaution was taken to prevent further dehydration of amorphous materials possibly present in the soil.

When all the samples were collected, the soils were sieved to remove the material greater than 2 millimeters (mm). This was accomplished by rubbing the coarser materials not passing through the screen by hand until little of the finer soil material remained on the gravel-sized fraction. The greater than 2-mm fractions were saved for weighing and visual examination. The less than 2-mm fractions were replaced in the plastic bags until after samples for mineralogical analyses were taken.

Sample Area Geologic Formations

The Price Peak soil was sampled on an area mapped by the U.S. Geological Survey as the Siletz River Volcanic Series. Baldwin (1959, p. 45) describes the well-exposed Siletz River outcrop in the area as a pillow basalt with interstratified beds of tuff. Zeolite minerals, volcanic glass and palagonite are abundant along the edge of the pillows and in the volcanic breccia.

The Yaquina Head soil was formed on Miocene volcanic rock which, according to Baldwin (1959, p. 19), is made up of coarse agglomerates and flows intruded by dikes of basalt.

Perpetua Head is a part of a series of volcanic rock of the late Eocene age with Cape Perpetua making up one of the bold basaltic headlands (Baldwin, 1959, p. 18).

The Hembre soil appears to be formed on an outcrop of the Siletz River Volcanic Series which, according to Baldwin (1959, p. 5), is the same as the formation called the Tillamook Volcanic Series by Warren, et al. (1945). This sequence consists of a series of submarine lava flows, breccias, and interstratified tuffs of great but unknown thickness.

The Mulkey sample site is on the north-facing slope near the summit of Mary's Peak. According to Baldwin (1959, p. 19), Mary's Peak is capped by an intrusive sill made up of granophyric gabbro. However, Roberts (1953) described a succession of rock changes from the top of Mary's Peak to the bottom of the sill. The Tyee Formation into which the sill intruded, has largely eroded away at the crest of Mary's Peak leaving a few small areas of hornfels formed in the contact zone. Aplitic dikes finger into the sill above the chilled contact zone. Granophyric diorite occurs below the chilled contact zone and gradually grades into a pegmatitic grano-phyric diorite. Granophyric gabbro makes up the bulk of the intru-sive sill, roughly occupying the lower two-thirds.

The Camas Ridge sample site is on sedimentary material mapped as being the upper Toledo formation. The Camas Prairie

soil is made up of alluvium derived from the same sedimentary material as the Camas Ridge soil. According to Baldwin (1959, p. 18), the upper sandy member of the Toledo Formation is variable, containing fine grained argillaceous tuffaceous sandstone and tuffaceous siltstones and shales with thin glauconitic beds resting upon the lower member of the formation, the Moody shale.

The Molock Creek sample was taken from an area mapped as the Yaquina Formation. The Yaquina Formation is described as predominately light-gray to brown, tuffaceous, and usually carbonaceous poorly consolidated sandstones, sandy tuffs, and interbedded or alternating tuffs and sandstones (Baldwin, 1959, p. 18).

EXPERIMENTAL PROCEDURES AND METHODS

An outline of sample treatments and the analyses performed on the various soil fractions and extracts are shown in Table 2.

Routine Soil Characterization Methods

Routine Chemical Methods

Ammonium acetate extractable cations, oxidizable carbon (C), and total nitrogen (N) were determined with the procedures reported by Alban and Kellogg (1959). Cation exchange capacity was determined with the method given by the U. S. Salinity Laboratory Staff (1954, p. 101). These analyses were carried out on the less than 2-mm air-dry soil samples by the Oregon State University Soil Testing Laboratory. Because of the very high organic matter content of most of the samples, the soils were ground to pass a 60-mesh screen to obtain more uniform subsamples for the C analyses. As a check, organic C was also determined by the dry combustion method of Young and Lindbeck (1964).

The procedure used by Dolman and Buol (1968) was used to determine crude humate (C.H.) and the humic (H.A.) and fulvic acid (F.A.) fractions. Crude humate was centrifuged and decanted from soil samples treated with 0.3 $\underline{N}$ NaOH for two hours. An aliquot of the C.H. was oven-dried and weighed. In another aliquot of the

Table 2. Outline of sample treatments and analyses performed on the various soil fractions.

General Characterization Analyses (All samples)	Mineralogical-Chemical (All samples) Pretreatment I	Mineralogical-Chemical (All samples) Pretreatment II
1. NH$_4$OAc Extractable Ca, Mg, Na, K	1. NaOAc Extractions	1. NaOAc Extractions
	2. Organic Matter Peroxidation	a. Ca, Mg, Fe, Al, Si analyses
	3. 1 C-B-D Fe-Removal Treatment	2. Organic Matter Peroxidation
2. Cation Exchange Capacity	4. Air-Jet Dispersion of Na-Saturated Samples	a. Ca, Mg, Fe, Al, Si analyses
		3. 3 C-B-D Fe-Removal Treatments
3 Oxidizable Carbon	5. Fractionation	a. Ca, Mg, Fe, Al, Si analyses
	a. X-ray diffraction of sands	4. Boiling Na$_2$CO$_3$ Treatment
4. Humus Fractionation	b. F.S., V.F.S., and C.Si.	a. Al, Si analyses
	(1) Heavy-light and magnetic mineral separations	5. Air-Jet Dispersion
5. Total Nitrogen		6 Fractionation
	(2) Mounted in Caedax	a. X-ray diffraction of sands
6. pH	(3) Petrographic examination	b. F.S., V.F.S., and C.Si.
	(4) Recleaned (more Fe-removal treatments)	(1) Heavy-light mineral and magnetic mineral separation
7. Apparent Bulk Density	(5) Mounted in Canada Balsam	(2) Mounted in Canada Balsam
	(6) Petrographic identification and grain counts	(3) Petrographic examination
8. 15-Bar Moisture Retention		(4) Recleaned (more Fe-removal treatments)
	c. < 2μ clay	(5) Mounted in Canada Balsam
	(1) X-ray diffraction	(6) Petrographic identification and grain counts
	(2) DTA analyses	c. < 2μ clay
	(3) 0.5 $\underline{N}$ NaOH dissolution	(1) X-ray patterns
	(a) Weight loss	(2) 0.5 $\underline{N}$ NaOH dissolution
	(b) Si, Al, Fe, Mg analyses	(a) Weight loss
	(4) Cation exchange capacity	(b) Si, Al, Fe, Mg analyses
	(5) Moisture retention	(c) X-ray diffraction
	(6) Fe-removal treatments	
	(a) X-ray diffraction	

C.H., 1 N HCl was added to precipitate the humic acid fraction.

The remaining portion after humic acid precipitation and separation

was considered to be the fulvic acid fraction. A sample of the F.A.

fraction was then weighed. The humic acid fraction was obtained by

weight difference between C.H. and F.A. taking into account the

added reagents.

The soil pH was determined in 1:1 soil-water and 1:1 soil-N

KCl suspensions with a Beckman Expandomatic pH meter. The pH

of 1:50, soil:N NaF suspensions was determined with a pH 0-14 range

glass electrode-calomel electrode combination on an Orion Research

Model 801 pH-meter. This indirect measure of anion adsorption was

suggested by the Soil Survey Staff (1967, p. 36).

Apparent Bulk Density

A measure of the "apparent bulk density" was obtained on the

less that 2-mm air-dry soil samples. A known weight of soil was

placed in a 5-cm diameter lucite tube and placed in a compacting

apparatus which dropped the tube 2.5 cm per turn of the concentric

crank. After 15 turns of the crank, the length of soil in the column

was measured to get a measure of the volume the soil occupied. The

bulk density was then calculated.

15-Bar Moisture Rentention

The moisture rentention at 15-bar pressure was determined with standard pressure membrane apparatus.

Sample Pretreatments for Mineralogy Studies

Two sequences, differing in amount of sample treatment and analyses, were used. In a preliminary study (Pretreatment I, Table 2), subsamples of all the less than 2-mm soil samples were treated with sodium acetate (NaOAc) and hydrogen peroxide (H_2O_2) for removal of organic matter (Jackson, 1956, p. 35). They were then treated once with citrate-bicarbonate-dithionate (C-B-D) for removal of free iron (Jackson, 1956, pp. 45-56). The samples were sodium saturated with 1 $\underline{N}$ NaCl and dispersed with the aid of an air-jet apparatus (Chu and Dividson, 1953). The less than 2 micron (μ) clay, fine silt (5-2μ) and medium silt (20-5μ) were separated according to the centrifugation procedures given by Jackson (1956, pp. 101-160). The remaining particles were separated in a nest of sieves. Either a subsample or all of each separated fraction was weighed to determine particle-size distribution.

Samples from five of the soil sites were given more extensive treatment and analysis (Pretreatment II, Table 2). Solution extracts were saved for chemical analysis after 1 $\underline{N}$ NaOAc, H_2O_2, and

iron-removal treatments. In contrast to Pretreatment I samples, those of Pretreatment II were treated three times with C-B-D for iron removal and then dispersed after a boiling sodium carbonate (Na_2CO_3) treatment (Jackson, 1956, p. 73). The Na_2CO_3 extract was also saved for chemical analysis.

After centrifuging the samples in the alkaline medium to separate clay, the samples were suspended several times in pH 3.5 HCl solutions to determine whether additional clay separation could be accomplished in the acid medium. Little or no additional clay was separated by the acid treatment.

Chemical Analyses of Extracts

Aliquots of the different Pretreatment II extracts were digested in $HCl-HClO_4$ and taken almost to dryness (Jackson, 1958, p. 305). The liquid and solid residues were filtered and washed several times with 0.5 $\underline{N}$ HCl. The solutions were saved for Ca, Mg, Fe and Al analyses (Jackson, 1958, p. 305).

Calcium, Magnesium and Iron Analyses

Analyses of Ca, Mg and Fe in the various extracts in the studies were made with the Model 303 Perkin-Elmer atomic adsorption spectrophotometer.

Aluminum Analyses

Aluminum was determined with aluminon reagent (Hsu, 1963).
Ten drops of 1:20 thioglycollic acid were added to each 50-ml volumetric flask before color development to reduce ferric Fe. It was found that the 10-drop addition of thioglycollic acid would prevent the interference of up to 20 ppm of ferric Fe. These results substantiated those found by Lindsay (1956, p. 28).

The aluminon lake formed with Al was not stable but Al determinations were reproducible if the color was developed 8 to 10 hours at room temperature and a set of standards were analyzed with each set of unknowns. Standards were prepared to contain comparable levels of reagents as those of the unknowns. Colorimetric measurements were made at 515 mμ with a Coleman Model 14 Spectrophotometer.

Silicon Analyses

Silicon was determined with a molybdosilicate blue method (American Public Health Association, 1961, pp. 228-229). The 1-amino, 2-naphthol, 4-sulfonic acid reducing agent used in this method produces a much more stable and reproducible color than $SnCl_2$, which is commonly used in other methods. The color adsorption can be measured at two wavelengths, 650 mμ and 815 mμ, with extremely high sensitivity being obtained at 815 mμ.

As stated in the discussion section of the method (American
Public Health Association, 1961, p. 225), large amounts of Fe,
color, turbidity, sulfide and phosphate are potential sources of inter-
ference. Organic matter was found to interfere in the colored NaOAc
extracts. Subsequently, the NaOAc and citrate-dithionate extracts
were peroxidized to remove the remaining organic matter. Jackson's
(1956, p. 59) procedure for the destruction of citrate was followed
for both extracts. After peroxidation the pH of the solutions were
adjusted to pH 8.5 with NaOH and digested on a steam plate for 2
hours to convert possible non-molybdate reactive Si to molybdate-
reactive Si. Hydrochloric acid was added to adjust the pH to 1.2 be-
fore the color was developed.

Known concentrations of $FeCl_3$ were added to check interfer-
ence due to Fe. Approximately 10 ppm of Fe in the final solution for
color development did not produce any significant interference in the
color development at either wavelength. In all the final unknown
solutions in which Si was determined the Fe concentrations, calcu-
lated from previous Fe analyses, were all less than 2 ppm. Thus,
it was considered very unlikely that Fe interfered with the Si analy-
ses made in the study.

Rock, Sand, and Silt Identification

Thin Sections

Thin sections were made from rock and saprolite fragments from the greater than 2-mm fractions of the Price Peak, Perpetua Head and Yaquina Head soils. The thin sections were examined with the petrographic microscope to obtain information concerning the parent rock.

Visual Estimations of Sand Mineralogy

The very coarse sand (2-1 mm), coarse sand (1.0-0.5 mm) and medium sand (0.5-0.25 mm) fractions were examined under a binocular microscope with a 30-power magnification. In conjunction, individual grains were separated from the coarser sand fractions for petrographic examination to make positive identifications of the minerals where it was feasible. Visual estimates of the mineralogy of the coarser sand fractions were made.

Light-Heavy Mineral Separations

Samples of 1 g or less were washed first with acetone and dried at 65° C. The separation of the light from the heavy minerals was carried out in bromoform ($\rho = 2.9$) in centrifuge tubes (Jackson, 1956, p. 478). After centrifuging the samples, the heavy portion on

the bottom of the centrifuge tube was frozen in acetone which had

been super-cooled by adding dry ice (Matelski, 1951). The light

fraction was poured off and rinsed into a filter paper. Then the

heavy fraction was thawed and washed into another filter paper. Both

fractions were washed several times with acetone, dried at 65° C

and weighed. Magnetic minerals in the heavy fraction were separated

with a hand magnet covered with a sheet of glycine paper.

Grain Mounts

The Pretreatment I sample grains initially were mounted on

petrographic slides in Caedax[1] with a refractive index of 1.55. It

was found that it was difficult to distinguish the quartz from feldspar

grains in this mounting media. Canada Balsam (refractive index

1.539) was used as the media for all subsequent grain mounts.

Nearly all the Pretreatment I samples showed evidence of

insufficient removal of Fe and O.M. Even after three whole-soil

iron-removal treatments had been applied on the Pretreatment II

samples, a very high percentage of the light mineral grains appeared

to be hematite or hematite-stained. Since hematite (specific gravity,

4.9-5.3; Jackson, 1956, p. 474) should have fallen with the heavy

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[1] Obtained from Ward's Natural Science Establishment, Inc., P. O.
Box 1749, Monterey, California.

grains, the light fractions of the samples were subjected to further iron-removal treatments. Iron-removal treatments were applied until the C-B-D extracts showed little or no yellow color. Identifications and grain counts were made on these more thoroughly cleaned samples. The difficulties in removing Fe stains in the light mineral fraction in this study is similar to those of Rojanasoonthon (1963, p. 23) who reported quite high percentages of iron-stained "rock fragments and aggregated grains" in the Alsea Basin red soils after three whole-soil iron-removal treatments.

Grain Counts

In the grain counting procedure with the petrographic microscope, counts along traverse lines of a mechanical stage were followed. For the fine sand and very fine sand grains mounts, all the grains in the field of view at pre-selected intervals along the traverse line were identified and counted. For the coarse silt mounts, grains falling under the horizontal cross-hair and a short distance on each side were identified and counted. Minimum counts of 300 light fraction fine sand, 400 very fine sand, and 500 coarse silt grains were made. Counts of 300 or more were made for the corresponding heavy fractions.

X-ray Diffraction of Sand Grains

In many cases where extensive weathering of the grains had occurred, positive identification of the minerals could not be made optically. In most cases this occurred with weathered aphanitic volcanic rock. Selected sand fractions were x-rayed to further characterize the weathering products. Individual grains of the more visibly weathered rock fragments were separated with tweezers from the very coarse sand and coarse sand sizes. These, along with whole "light" fine sand and very fine sand sizes were ground with a mullite mortar and pestle, deposited on glass slides, mixed with distilled water and dried. They were then analyzed by x-ray diffraction. Since Na was the only cation used in the final C-B-D iron-removal treatments, it was assumed that any negatively-charged surface was saturated with Na.

X-ray diffraction maxima for differentiating clay minerals and other mineral species are listed in many publications. Among these are American Society for Testing Materials (1945); Jackson, 1955, pp. 211-213; Brown (1961); Whittig (1965, pp. 689-696); and Grim (1968, pp. 120-164).

X-Ray Diffraction Equipment

X-ray diffraction patterns of sand were obtained with a General Electric XRD-5 diffractometer equipped with a Geiger-Meuller tube

and a Leeds and Northrup recorder. Nickel-filtered Cu K-alpha radiation generated at 50 kilovolts and 16 milliamperes was used. A 1° divergent slit, a medium resolution collimater and a 0.2° receiving slit were employed. Scans were run from 3° 2 to at least 30° 2 and, in a few cases, to 45° 2 . All samples x-rayed with a rate meter setting of 500 C.P.S. and a time constant of 4.

Clay samples (in a following section) were x-rayed at varying rate meter and time constant settings.

Clay Characterization

Cation Exchange Capacity

Cation exchange capacities of the less than 2µ clay were determined on the Pretreatment I (1 iron-removal) samples which had been stored in NaCl. Approximate 1-g samples were washed with methanol to a negative $AgNO_3$ test. The clay was then extracted three times with 1 $\underline{N}$ $CaCl_2$. The first and third extractions were shaken on a reciprocal shaker for 10 minutes. The second extraction was shaken over night. The Na in the $CaCl_2$ extract was determined with the Model 303 Perkin-Elmer atomic absorption spectrophotometer.

Moisture Adsorption

The Ca-saturated clays from the cation exchange determination were washed with methanol until free of Cl. The clays were then dried at 65° C, ground with a mullite mortar and pestle, placed in a dessicator over saturated $Mg(NO_3)_2 \cdot 6H_2O$, and evacuated. After an elapse of several weeks, a portion of each sample was placed in a weighing can, dried at 110° C for 24 hours and the weight loss determined.

Differential Thermal Analysis

DTA analyses were performed on the Ca-saturated Pretreatment I clays which had been equilibrated over saturated $Mg(NO_3)_2 \cdot 6H_2O$ at approximately 54% relative humidity. The analyses were made with a DuPont 900 Differential Thermal Analyzer. Patterns were run from room temperature to approximately 1050° C at a heating rate of 20° C per minute. The samples were run in microcups with an alundum reference material and platinum-platinum/rhodium thermocouples. A nitrogen atmosphere was employed to reduce exothermic reactions due to possible incomplete removal of O.M.

0.5 N NaOH Dissolution

The 0.5 N NaOH dissolution treatment of Hashimoto and Jackson (1959) was used to estimate the amorphous materials associated

with the clay fractions. The Na-saturated clays were allowed to adjust to laboratory atmospheric conditions in open vials. Small sub-samples of each clay were dried at 110° C in order to adjust the data to an oven-dry basis.

A sequence consisting of boiling each sample in 0.5 $\underline{N}$ NaOH followed by two C-B-D iron-removal treatments was used. However, two different clay to NaOH ratios were used within the sequence. Clay:NaOH suspensions of 1:1000 and 1:1500 were used for Pretreatment I samples.

The Pretreatment II samples were boiled only in the 1:1000 clay:NaOH suspension. The NaOH was brought nearly to a boil before adding the clay sample in order to reduce contact time during the heating process. After boiling 2.5 minutes in stainless steel beakers, the suspensions were cooled and centrifuged. Hydrochloric acid was added to the decanted supernatant NaOH to slightly acidify the solution. These solutions were analyzed for Si and Al. The C-B-D extracts were saved for Al, Si, Fe, and Mg analysis.

After the iron-removal treatments were completed, the remaining clay was flocculated with 1 $\underline{N}$ NaCl, washed once with water, then with methanol until the Cl test was negative, and then dried at 110° C in previously tared glass bottles. The weight loss due to the boiling NaOH and iron-removal treatment sequence was determined.

The clay fractions were analyzed by x-ray diffraction after

various stages of cleaning and other treatments. The Pretreatment I

clays were analyzed after : (1) the initial clay separation, (2) further

iron-removal treatments and (3) after the 0.5 $\underline{N}$ NaOH dissolution and

C-B-D treatments. The Pretreatment II clay samples were analyzed

after: (1) the initial clay separation and (2) the 0.5 $\underline{N}$ NaOH dissolu-

tion and C-B-D iron-removal treatments.

Cation saturation and treatment sequences. The clay fractions

were Mg-saturated by washing four times with 1 $\underline{N}$ $MgCl_2$ followed by

two or more washings with distilled water. The clay was oriented on

two or more glass petrographic slides with a micro-spatula accord-

ing to the procedure of Theisen and Harward (1962). The slides were

air-dried and placed in a dessicator over a saturated $Mg(NO_3)_2 \cdot 6H_2O$

solution with a relative humidity (R.H.) of about 54% and evacuated.

After equilibrating the slides at least 24 hours, the slides were

analyzed. Control of the relative humidity (R.H.) of the clay was

accomplished by blowing air passed through a saturated

$Mg(NO_3)_2 \cdot 6H_2O$ solution directly onto the slide.

After x-ray analysis at 54% R.H., slides giving approximately

equal peak intensities were solvated with ethylene glycol (Kunze,

1955) and glycerol vapors (Brown and Farrow, 1956). One slide was

solvated with ethylene glycol vapor by heating a can containing ethy-

lene glycol at 65° C with the slide suspended on a screen above the

liquid for 2 or more hours. After x-ray analysis of the ethylene

glycol solvated slides, the slides were dried at 65° C to drive off the

ethylene glycol, then resolvated and x-rayed again. This was done

because a better resolution of 14 and 17Å peaks was obtained with the

latter treatment for most of the samples in the study. It was found

that some clays expanded more if the glycerol or ethylene glycol was

preheated before placing the slides in the can. Therefore, preheat-

ing of the cans was adopted as a standard practice.

Slides of a standard montmorillinite clay receiving the same

treatments were included in each sequence to monitor the effective-

ness of the treatments.

Clay samples saturated with potassium (1 N KCl followed by

washing with distilled water) were dried in an oven at 105° C over

night or longer. The slides were placed in a dessicator over drierite

to cool after heating. The slides were then x-rayed while air passing

through drierite was blown onto the slide area being x-rayed. The

R.H. of the air blown onto the slide was probably 0-3%. This treat-

ment was effective for preventing the rehydration and change in

lattice spacing of the standard K-saturated montmorillinite. After

x-raying in the dry atmosphere, the slides were placed in a dessi-

cator for several days to equilibrate at 54% R.H. over saturated

$Mg(NO_3)_2 \cdot 6H_2O$. X-ray diffraction patterns were then obtained

while air at 54% R.H. was being blown on the slides. Diffraction

patterns were then obtained on the K-slides after heating to 300° and 550° C. Dry air was used for the slides heated to 300° C. Some of the K-saturated clays were heated at 425° C to observe the effect on 7-7.5 angstrom ($\overset{\circ}{A}$) peaks found at lower temperatures.

RESULTS AND DISCUSSION

Soil Chemical, Organic and Physical Properties

Properties of the <2-mm Soil Samples

Results of chemical and physical analyses performed on the

less than 2-mm soil are presented in Table 3.

pH. All soils in the study are strongly acidic. The soil:1 $\underline{N}$

KCl pH ranges from a low of 3.18 for the Molock Creek A1 sample

to 4.63 for the Price Peak B21 sample. In most cases, the pH in-

creases slightly with depth. The pH of the soil:water suspension is

higher for each soil at each depth than the soil:1 $\underline{N}$ KCl suspension.

Pionke and Corey (1967) reported that low pH values in KCl as com-

pared with pH in water was related to high to "exchangeable Al" con-

tests. The soil pH in water was less reproducible than in KCl.

Base saturation. The base saturation of the samples is very

low. The majority are 10% or less base saturated. The base satu-

ration of these soils falls within the same range as those reported

for the moderately and highly leached allophanic soils formed from

volcanic ash and pumice in New Zealand (New Zealand Soil Bureau, 1968).

Cation exchange capacity. Very high cation exchange capaci-

ties (CEC) are closely related to the very high organic matter (O.M.)

contents of the soils. The increase in the CEC with increasing O.M.

Table 3. Chemical and physical properties of the <2-mm air-dry soil samples.

Soil and Horizon	pH (H_2O)	pH (KCl)	Extractable Cations				CEC	Base Sat.	O.M.	N	C/N	Bulk Density
			Ca	Mg	Na	K						
			me/100 g					%	%	%		
Price Peak												
A12	5.10	4.60	17.0	5.1	0.3	2.0	100	24	33.2	0.669	28.7	0.62
B21	5.15	4.63	10.8	3.4	0.2	1.5	67	24	17.8	0.410	25.2	0.76
B22	5.35	4.44	8.0	3.8	0.2	0.9	43	30	6.1	0.168	21.1	0.97
Yaquina Head												
A11	5.25	4.52	4.4	8.2	2.3	1.3	56	3	12.0	0.342	20.3	0.92
IIA12	4.90	4.13	5.0	9.4	3.7	1.8	97	20	32.5	0.961	19.6	0.76
IIAC	5.15	4.19	1.7	4.1	2.0	0.8	73	12	16.2	0.396	23.7	0.78
IIC	4.80	4.32	0.8	2.7	1.5	0.8	62	9	5.7	0.165	19.9	0.75
Perpetua Head												
A12	4.60	4.17	1.2	1.5	0.6	1.0	82	5	31.1	0.859	21.0	0.67
A13	4.80	4.47	0.5	1.1	0.6	0.7	68	3	20.5	0.585	20.3	0.73
C	4.80	4.59	0.5	1.5	0.6	0.6	62	5	15.6	0.477	19.0	0.74
Perpetua Beach												
A12	5.05	4.47	1.6	4.5	1.6	0.9	60	14	16.0	0.524	15.4	0.89
B2	5.15	4.42	1.4	3.6	1.5	0.9	62	12	14.6	0.540	15.6	0.79
Hembre												
A1	4.10	3.82	1.5	1.7	0.3	0.5	68	6	19.6	0.408	27.9	0.69
A3	4.20	3.87	0.2	0.5	0.3	0.2	58	2	16.6	0.308	31.2	0.78
B21	4.35	3.95	0.1	0.2	0.2	0.1	47	1	7.7	0.142	31.5	0.83
Cascade												
A11	4.40	4.04	0.2	0.7	0.4	0.4	58	3	15.7	0.383	23.8	0.75
A12	4.30	4.08	0.1	0.5	0.4	0.3	58	2	12.3	0.310	23.0	0.76

Table 3. continued

Soil and Horizon	pH (H_2O)	pH (KCl)	Extractable Cations				CEC	Base Sat.	O.M.	N	C/N	Bulk Density
			Ca	Mg	Na	K						
			me/100 g					%	%	%		
Tillamook Head												
A (CT-4)	4.05	3.53	1.8	2.0	0.6	0.3	79	6	32.5	0.665	28.3	0.81
A (CT-5)	4.25	3.91	0.2	0.8	0.7	0.5	97	2	37.8	0.683	32.1	0.61
Mulkey												
A11	3.80	3.55	0.4	0.5	0.2	0.4	55	3	19.1	0.571	19.4	0.82
A12	4.00	3.79	0.1	0.1	0.1	0.2	41	1	13.3	0.348	22.1	0.92
Quillayute												
A11	4.60	4.09	2.5	1.7	0.3	0.5	70	7	24.0	0.605	23.1	0.79
A12	4.55	4.02	0.8	0.9	0.3	0.4	72	3	24.5	0.571	23.5	0.76
A13	4.55	4.00	0.2	0.4	0.2	0.2	65	2	20.9	0.487	24.9	0.71
Camas Prairie												
A	3.95	3.49	0.6	1.6	0.3	1.2	68	5	16.6	0.699	13.7	0.85
C	4.15	3.37	0.2	1.6	0.3	0.3	52	5	3.6	0.162	12.7	0.94
Camas Ridge												
A11	4.00	3.59	0.1	0.7	0.3	0.6	67	3	14.0	0.452	18.0	0.80
A12	4.00	3.65	0.1	0.4	0.3	0.4	58	2	7.5	0.270	16.0	0.80
Molock Beach												
A1	4.10	3.73	1.0	3.2	1.8	0.7	70	10	31.1	0.648	27.8	0.70
AC	4.80	4.33	0.6	1.5	1.8	0.5	44	10	11.1	0.281	23.0	0.82
C	4.50	4.23	0.1	0.7	1.0	0.4	37	6	5.2	0.121	24.8	0.87
Molock Creek												
A1	3.55	3.18	1.0	1.4	0.9	0.6	73	5	25.2	0.480	30.4	0.75
AC	4.05	3.88	0.1	0.2	0.3	0.1	56	1	10.5	0.214	28.5	0.86

is variable for individual soils in the study. In general, the CEC

increase per percent increase in O.M. fall within a range of about 1

to 2 me and averaged about 1.5 me. The variability could be due to

several other interrelated factors, such as amount, type and pH-

dependency of the clay CEC or possibly even the composition of the

O.M. itself.

Exchangeable Cations. Magnesium is the predominate

NH_4OAc extractable cation in all soils except for the Price Peak soil

in which Ca is dominant. For most of the soils, the prevalence of

Mg over Ca might be explained by their close proximity to the ocean

where fog and mist can transport and deposit considerable Mg. How-

ever, higher exchangeable Na contents than what are found would be

expected if fog and mist were important sources of cations.

Organic matter. The O.M. percentages of all the soils are

considered very high for well-drained soils, especially in the surface

depths. The surface horizons of six soils in the study reach or ex-

ceed the lower O.M. limit set for the histic epipedon in the Com-

prehensive Soil Classification system (Soil Survey Staff, 1960). O.M.

extends to a considerable depth for many of the soils--a notable

example being the Perpetua Head soil with 15.6% O.M. in the 100-

122 cm (40-48 in. horizon) depth. These thick layers of accumulated

O.M. have caused considerable speculation in the past as to the ex-

tent of colluvial activity in the profile development of many of the

soils near the Coast Range. On the other hand, O.M. occurring at

a considerable depth might have been the result of an illuvial accumu-

lation.

Soil O.M. build-up is generally related to moist or wet condi-

tions and/or cool to cold temperatures. Large accumulations of soil

O.M. in tropical regions where O.M. accumulation was expected to

be low were reported to be related to large amounts of Al found in

the soils (Kawaguchi and Kyume, 1959; Harris, 1963). Mutatkar and

Pritchett (1966) postulated that Al could influence O.M. decomposi-

tion rates through (1) strong adsorption of Al on the O.M., forming

microbiologically stable organo-Al complexes, or (2) through toxic

effects of Al on microbial activity. These authors reported signifi-

cant decreased in CO_2 production in muck soil with increasing Al

contents when the soil was maintained below pH 4. Slow mineraliza-

tion of both N and C in New Zealand soils high in allophane content

was reported by Broadbent, et al (1964).

C/N ratio. The C/N ratios are highest for the forest soils or

those showing some evidence of past forestation. The C/N ratios of

the Camas Prairie soil, 13.7 and 12.7 in the A and C horizons, re-

spectively, are about the same as those found in normal agricultural

and grassland soils. Relatively high C/N ratios (15 to 30) were

reported for New Zealand humic allophane soils (Wright, 1963).

Most of C/N ratios of the soils in the study fall within the 15 to 30 ratio.

Bulk density. In general the measure of the "apparent bulk density", while not a standardized method, shows that the soils in the study are low bulk density materials. To a large extent, this can be related to the high O.M. content and the strong granulation of the soils. Humic allophane soils formed from volcanic ash commonly have a bulk density of 0.6 (Gibbs and Wells, 1965).

Humic matter. The humic matter (H.M.) and the humic acid/fulvic acid (H.A./F.A.) ratios (Table 5) were determined to aid in answering several questions. The first question was whether the method would show gross differences in the character of the O.M. accumulated from the fairly diverse vegetation types growing on the soils. Gross character differences between groups, such as the "black-colored" soils and the "brown-colored" soils, might possibly be used as a logical basis for delineating them in a classification scheme. Other questions were: (1) whether or not the data might provide information as to the extent of colluvial activity versus illuvial activity in soil O.M. accumulation; and (2) whether or not the data would provide information to help explain the Fe and Al distribution in the soil profiles.

Increasing proportions of H.M. extracted from O.M. and lower H.A./F.A. ratios can be taken as a general indication of an

increased degree or stage of O.M. decomposition (Rode, 1962).

Wright and Schnitzer (1960) assert that the F.A. fraction is more

mobile than the H.A. fraction. The H.M./O.M. appears to be use-

ful for delineating soils with considerable amounts of undecomposed

or relatively undecomposed plant material. The H.M./O.M. ratio

of 0.20 for the Price Peak soil (Table 4) results from significant

amounts of undecomposed root and other plant material which can be

seen in the sample.

Assuming that F.A. has greater mobility than H.A., an in-

crease in the proportion of H.M. extracted from O.M. along with a

decrease in H.A./F.A. as the soil depth increases might be inter-

preted as evidence for illuviation of O.M. These relations are found

in the profiles of five soils, the Price Peak, Camas Prairie, Camas

Ridge, Molock Beach, and Molock Creek, and indicate that O.M.

eluviation has taken place.

Deviation from these trends in the two factors might indicate

colluvial activity, alluvial activity, or other profile discontinuities.

The surface eolian deposit on the Yaquina Head is indicated by a

lower A11 H.A./F.A. ratio than in the IIA12 horizon. Colluvial

activity is indicated by decreasing H.M./O.M. ratios for the Perpetua

Head, Perpetua Beach, Hembre, and Mulkey soils. The decreased

H.M./O.M. with depth might result from reduced microbiological

activity with depth. The H.A./F.A. ratios of these soils decrease

Table 4. Properties of the humic fraction of the <2-mm air-dry soil samples.

Soil	Horizon	Humic Matter	H.M./ O.M.	Humic/ Fulvic Acid
		%		
Price Peak	A12	6.6	0.20	1.64
	B21	4.3	0.24	0.53
	B22	1.9	0.31	0.03
Yaquina Head	A11	3.5	0.29	0.24
	IIA12	9.3	0.29	2.01
	IIAC	8.0	0.50	0.78
	IIC	3.1	0.54	0.02
Perpetua Head	A12	16.7	0.54	1.59
	A13	8.8	0.43	0.75
	C	5.6	0.36	0.37
Perpetua Beach	A12	7.8	0.49	0.64
	B2	6.4	0.44	0.49
Hembre	A1	8.6	0.44	1.00
	A3	7.3	0.44	0.67
	B21	2.7	0.35	0.02
Cascade Head	A11	5.1	0.32	0.27
	A12	5.8	0.47	0.31
Tillamook Head	A (CT-4)	12.4	0.38	1.71
	A (CT-5)	24.5	0.65	3.10
Mulkey	A11	8.2	0.43	1.16
	A12	3.3	0.25	0.38
Quillayute	A11	10.6	0.44	1.14
	A12	12.4	0.51	1.42
	A13	8.1	0.39	0.77
Camas Prairie	A	5.8	0.35	1.20
	C	2.2	0.61	0.15
Camas Ridge	A11	5.1	0.36	0.51
	A12	2.7	0.36	0.04
Molock Beach	A1	11.1	0.36	1.09
	AC	8.1	0.73	0.48
	C	6.1	1.12	0.28
Molock Creek	A1	13.1	0.52	1.89
	AC	10.8	1.03	0.66

consistently with depth, however. Thus, colluviation and illuviation cannot be delineated precisely for these four soils. In general, the trends in H.M./O.M. appear to have some value for sustantiating field observations concerning colluviation. A more recent alluvial deposition in the Quillayute profile (A11) is indicated by a higher H.A./F.A. ratio in the A12 horizon. The larger gravel percentage in the Quillayute A11 horizon is another indication of the profile discontinuity.

The data, in general, do not show gross differences in the character of the H.M. between soils. Thus, the lack of gross difference would provide support for an argument that the soils should be classified within the same great group or subgroup.

Elements Released in the Pretreatment Extracts

Aluminum has been reported to be complexed by fulvic and other humic acids (Wright, 1963). A low divalent base status in Ando soils has often been reported (Thorp and Smith, 1949; Wright, 1963). The cleaning and dispersion extracts were analyzed to obtain indications of cation chelation as well as amorphous material dissolution (Table 5).

Ca and Mg. Except for the Mulkey series, the pH 5 NaOAc reagent extracted more Ca and Mg, and in particular Ca, than the pH 7 NH_4OAc extractant (Table 3). The additional amount extracted

Table 5. Elements removed by the various extractants, calculated on the 110° C oven-dry basis.

Soil and Extract	Horizon	Ca	Mg	Fe	Al	Si
		me/100 g		mmol/100 g		
Price Peak						
NaOAc	A12	27.40	6.40	0.08	1.41	0.11
H_2O_2-NaOAc		13.80	1.63	8.99	39.55	2.23
C-B-D		<0.01	0.66	61.19	21.16	3.96
Na_2CO_3		--	--	--	0.49	0.22
Total		41.21	8.69	71.26	62.61	6.52
NaOAc	B21	16.50	4.03	0.12	2.08	0.18
H_2O_2-NaOAc		7.79	1.22	4.32	32.21	1.64
C-B-D		<0.01	0.77	80.11	31.02	4.65
Na_2CO_3		--	--	--	0.28	0.17
Total		24.30	6.02	84.55	65.59	6.64
NaOAc	B22	10.50	4.05	0.09	1.73	0.22
H_2O_2-NaOAc		3.64	1.10	0.95	27.33	1.09
C-B-D		<0.01	0.69	90.23	38.86	4.38
Na_2CO_3		--	--	--	0.37	0.23
Total		14.15	5.84	91.27	68.29	5.91
Yaquina Head						
NaOAc	A11	8.05	10.41	0.03	1.62	0.17
H_2O_2-NaOAc		1.76	0.90	3.01	20.75	1.38
C-B-D		<0.01	0.75	49.54	18.18	3.89
Na_2CO_3		--	--	--	0.18	0.34
Total		9.82	12.06	52.55	40.23	5.78
NaOAc	IIA12	9.85	11.61	0.08	3.11	0.22
H_2O_2-NaOAc		5.16	2.49	7.59	47.81	1.30
C-B-D		<0.01	1.45	85.00	24.02	4.51
Na_2CO_3		--	--	--	0.11	0.38
Total		15.02	15.55	92.67	75.05	6.47
NaOAc	IIAC	3.48	5.86	0.14	6.26	0.44
H_2O_2-NaOAc		1.36	1.44	2.88	34.39	1.75
C-B-D		<0.01	0.95	94.53	51.48	4.84
Na_2CO_3		--	--	--	0.23	0.14
Total		4.75	8.25	97.55	92.37	7.17

Table 5. continued

Soil and Extract	Horizon	Ca	Mg	Fe	Al	Si
		me/100 g		mmol/100 g		
NaOAc	IIC	1.82	7.17	0.12	4.63	0.75
H_2O_2-NaOAc		0.57	1.11	1.33	14.01	1.21
C-B-D		<0.01	0.67	103.14	53.89	5.41
Na_2CO_3		--	--	--	0.19	0.16
Total		2.40	6.95	104.58	72.72	7.53
Perpetua Head						
NaOAc	A12	2.78	2.02	0.10	5.67	0.31
H_2O_2-NaOAc		1.93	0.73	7.93	78.64	2.56
C-B-D		<0.01	1.42	67.58	48.98	6.53
Na_2CO_3		--	--	--	0.42	0.23
Total		4.72	4.17	75.61	133.71	9.63
NaOAc	A13	1.29	1.54	0.09	4.76	1.13
H_2O_2-NaOAc		1.04	0.68	3.12	46.36	1.78
C-B-D		<0.01	1.38	83.28	62.39	4.96
Na_2CO_3		--	--	--	0.43	0.12
Total		2.34	3.50	86.49	113.94	7.99
NaOAc	C	1.16	2.96	0.15	6.72	0.85
H_2O_2-NaOAc		0.67	0.61	1.61	28.97	1.78
C-B-D		<0.01	1.46	90.66	65.44	4.51
Na_2CO_3		--	--	--	0.39	0.19
Total		1.84	4.93	92.42	101.52	7.33
Mulkey						
NaOAc	A11	0.33	0.33	0.13	2.08	0.16
H_2O_2-NaOAc		0.47	0.26	3.79	30.48	0.32
C-B-D		<0.01	0.45	52.70	18.95	4.14
Na_2CO_3		--	--	--	0.24	0.41
Total		0.81	1.04	56.62	51.75	5.03
NaOAc	A12	0.14	0.08	0.12	2.40	0.55
H_2O_2-NaOAc		0.26	0.17	2.61	26.46	0.22
C-B-D		<0.01	0.41	56.05	14.62	4.33
Na_2CO_3		--	--	--	0.30	0.36
Total		0.41	0.66	58.78	53.78	5.46

Table 5. continued

Soil and Extract	Hor- izon	Ca	Mg	Fe	Al	Si
		me/100 g			mmol/100 g	
Quillayute						
NaOAc	A11	3.74	1.71	0.08	4.61	0.10
H_2O_2-NaOAc		0.67	0.74	4.51	51.90	1.47
C-B-D		<0.01	0.81	63.53	34.81	4.92
Na_2CO_3		--	--	--	0.32	0.22
Total		4.42	2.26	68.12	91.64	6.71
NaOAc	A12	1.35	0.96	0.06	5.64	0.16
H_2O_2-NaOAc		1.15	0.56	4.83	55.59	1.32
C-B-D		<0.01	0.77	69.33	41.91	5.43
Na_2CO_3		--	--	--	0.34	0.22
Total		2.51	2.29	74.22	103.48	7.13
NaOAc	A13	0.64	0.41	0.07	8.01	0.30
H_2O_2-NaOAc		0.51	0.33	3.81	46.84	1.36
C-B-D		<0.01	0.69	70.34	47.05	5.89
Na_2CO_3		--	--	--	0.36	0.21
Total		1.16	1.43	74.22	102.26	7.76

appears to be somewhat related to the O.M. content of the particular

horizon. That O.M. has the ability to complex with metallic ions

and hydrous oxides has long been postulated (Jones and Wilcox, 1929).

Schnitzer (1969) reported that both Ca and Mg are complexed by

fulvic acid with the stability constant of Ca-fulvic acid greater than

Mg-fulvic acid. Stability constants for humic acid fractions appear

to be lacking in the literature at this time. The initial NaOAc ex-

tracts, particularly those from surface horizons, were highly

colored. The analyses of the digested extracts probably includes

some organically complexed Ca and Mg in addition to that considered

as exchangeable.

Additional Ca and Mg were released during the O.M. peroxi-

dation treatments (H_2O_2 plus pH 5 NaOAc). However, the amount

released was generally lower than in the initial NaOAc extract. The

amount of Ca release was generally greater than Mg release, indi-

cating more complexed Ca than Mg. Some Mg was extracted during

the C-B-D iron-removal treatment, whereas, little or no Ca was ex-

tracted. The amount of Mg extracted in C-B-D treatments tended to

be more uniform with soil depth than in the previous NaOAc ex-

tractants. The latter Mg may have come from the dissolution of soil

minerals, such as pyroxene, amphibole or chlorite.

Fe. Relatively small amounts of Fe (approximately 0.1

mmol/100 g or less) were extracted with the initial pH 5 NaOAc

treatment from the different soils and different horizons. The
amount of Fe extracted during O.M. peroxidation increased over that
from the initial NaOAc extraction but, in general, decreased with de-
creasing horizon depth. The decrease in extracted Fe as the O.M.
decreases with horizon depth indicates that Fe release is related to
O.M. content. Schnitzer and Skinner (1965) reported greater Fe
than Al chelation by O.M. from the B_h horizon of a Spodosol (Podzol).
Thus, it seems reasonable to assume that Fe complexed by O.M. is
being released during the peroxidation treatments. However, the
results in this study are not consistent with those of Schnitzer and
Skinner (1965). Relatively small amounts of Fe appear to be chelated
by O.M. The Fe removed during C-B-D treatments and total Fe
removed by all treatments increases with increasing horizon depth
for each soil. The distribution of Fe in the soil profiles indicates a
gradual downward displacement of Fe rather than distinct eluvial and
illuvial horizons such as those found in the Spodosols. The relative
differences between the total Fe of the surface horizons and of the
lower horizons sampled are not great. Thus, the data indicate that
extensive Fe displacement from the surface horizons of the soils has
not taken place. However, the predominance of the F.A. component
in the H.M. of the lower horizons and indications of Fe-O.M. com-
plexing furnishes a plausible mechanism for the limited displacement
of Fe that has taken place.

<u>Al</u>. Compared on a molar basis, substantially more Al than

Fe was extracted with the initial pH 5 NaOAc extraction treatment.

Pionke and Corey (1967) used a pH 4.8 NH_4OAc solution to extract

"exchangeable plus non-exchangeable Al". The extraction properties

of the pH 5 NaOAc and the pH 4.8 NH_4OAc are probably quite similar.

The pH 4.8 NH_4OAc solution has been reported to dissolve unaged

$Al(OH)_3$ (Pratt and Blair, 1961). It was postulated that hydroxy-Al

polymers and Al complexed by O.M. were removed by this reagent,

also (Jackson, 1963; McLean, et al., 1964).

The extractions made during the O.M.-peroxidation treat-

ments removed considerably more Al than the initial NaOAc treat-

ment. As in the case of Fe, this appears to be related to metal

complexing with O.M. (Figure 2). Although limited, the data show a

reasonably good linear relationship between extracted Al and the

oxidizable C for a particular soil. The data for the five soils appear

to follow two or possibly three different slopes. The data points for

the Perpetua Head soil and the Quillayute series soil fall closely on

the same line with the same slope.

In Figure 3 Al+Fe extracted during peroxidation are plotted

versus the percent H.M. extracted from the soils with 0.3 $\underline{N}$ NaOH.

This plot brings the data for individual determinations more closely

to fitting the same slope but somewhat increases the degree of scatter

for individual soils. The amount of Al in each data point is
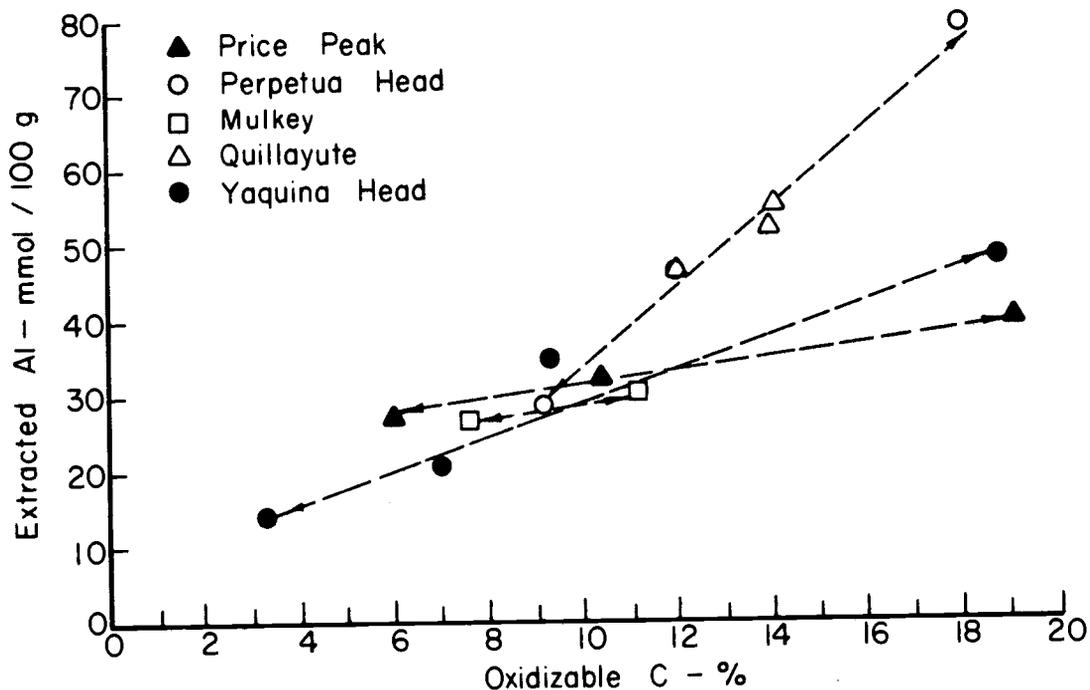
Figure 2. The relationship between organic C of the soils and Al removed in NaOAc during peroxidation.
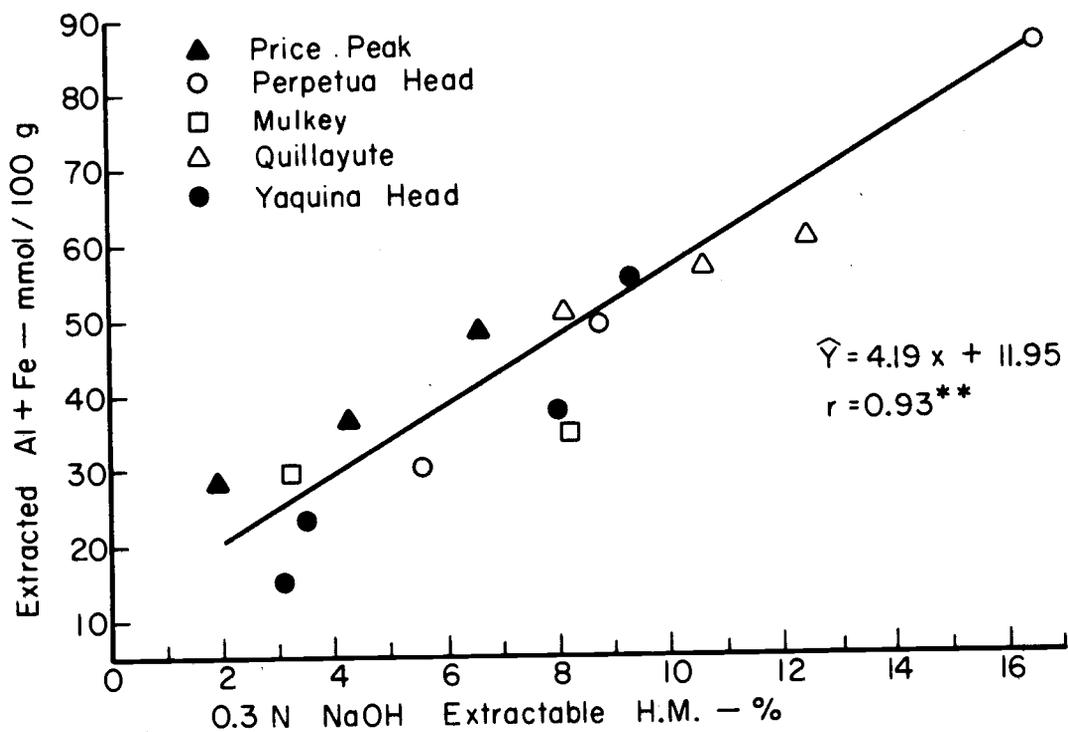
Figure 3. Al and Fe in the peroxidation extracts and relationship to alkali soluble humic matter.

approximately 10 times that of extracted Fe. However, a slightly

improved correlation is obtained when the Fe is included. A sur-

prisingly good correlation coefficient (r = 0.93) is obtained from this

relationship.

Poorer relationships were obtained when Al and Fe, alone or

together, were plotted versus either the percent humic or fulvic acid.

This may indicate that the Al and Fe extracted during peroxidation

was complexed by both the humic and fulvic fractions. The large

predominance of Al extracted over that of Fe tends to indicate that

Al is the principle metal complexed in these soils. This is opposite

that reported by Schnitzer and Skinner (1965). However, some Fe

possibly complexed by the O.M. may have precipitated as $Fe(OH)_3$

when the O.M. was peroxidized. This precipitation generally takes

place above pH 2.5.

The Al extracted during the C-B-D Fe-removal treatments

increases with increasing depth for all the soils. Extracted Al in

C-B-D reagents were one-third to two-thirds that of Fe. Possible

sources from which this Al was extracted are gibbsite, hydroxy-Al

interlayer material from chloritic intergrade clay, and unstable

amorphous alumino-silicate. All of these components were identified

in the clay-sized fraction of the soils (the data are presented in a

following section). Dissolution of poorly crystalline gibbsite is the

most likely source of the extracted Al for at least part of the soils.

Gibbsite x-ray diffraction peaks (4.83 $\overset{o}{A}$) disappeared from Pretreatment I clay samples after the clay had been given several additional C-B-D iron-removal treatments.

Compared with the previous treatments, the boiling 2% Na_2CO_3 treatment extracted the least Al. This amounted to less than 0.5 mmol/100 g in all cases.

<u>Si</u>. The Si extracted in the initial NaOAc treatment is low when compared on a molar basis with Al. For most of the soils, the amount of Si extracted increased slightly with depth. Larger amounts of Si were extracted during the O.M. peroxidation than the initial NaOAc treatments. The Si extracted during O.M. peroxidation shows no consistent depth relationship between soils. The source and the significance of the Si extracted with these treatments if difficult to evaluate.

The C-B-D iron-removal treatments, resulted in a successive increase in the Si removal. This could very possibly be related to the decomposition of unstable amorphous alumino-silicate material. The data show a trend for more Si extraction as more Al is extracted with the C-B-D treatments. The Si extracted in the Na_2CO_3 decantate was low compared with the C-B-D values.

Particle-Size Distribution and Texture

The data for particle-size distribution and texture for the samples are shown in Table 6. There is no consistent trend in the differences in the sand, silt or clay percentages determined by the two somewhat different procedures (Appendix II). More dispersals and decantations were made during the Pretreatment II clay separations than for the Pretreatment I samples. This appears to be reflected in the larger clay percentages for the Quillayute and Mulkey samples. The other Pretreatment II sample clay percentages are generally, but not consistently, lower than those of Pretreatment I. However, in only one case do these variations change the textural grade of the sample--the Yaquina Head IIAC horizon.

The data do not show much evidence of clay eluviation in the soils. In fact, in many cases, the clay contents either show little or no difference with depth or show a decrease with depth. The mechanical analyses show that texture estimated in the field was almost always consistently low.

Table 6. Mechanical analyses of soil samples given Pretreatment I.

Hor-izon	Gr. >2.0 mm	V.C.S. 2-1	C.S. 1-.5	M.S. .5-.25	F.S. .25-.1	V.F.S. .1-.05	C.Si. .05-.02	M.Si. .02-.005	F.Si. .005-.002	C <.002	Tex-ture
Price Peak											
A12	75.6	7.1	6.1	3.4	6.1	6.7	17.2	17.8	7.4	28.2	CL
B21	64.2	8.2	6.6	3.5	6.4	7.2	18.1	19.3	4.7	26.0	L
B22	56.5	9.1	7.4	4.3	6.9	8.4	14.4	19.9	7.9	21.7	L
Yaquina Head											
A11	4.0	0.4	2.4	39.9	22.1	6.4	4.2	6.8	3.7	14.1	SL
IIA12	18.1	1.1	3.6	7.6	10.2	7.0	6.1	18.2	9.2	37.0	CL
IIAC	27.4	2.8	5.8	11.0	13.0	9.0	9.1	15.8	7.3	26.2	L
IIC	35.2	0.8	3.5	6.4	10.2	8.1	10.0	18.3	6.9	35.8	CL
Perpetua Head											
A12	33.7	1.5	3.3	3.2	9.0	10.0	9.7	25.3	10.0	28.0	CL
A13	34.6	0.7	2.5	2.5	8.2	8.6	13.2	20.5	4.7	39.1	CL
C	37.3	1.1	3.0	2.8	8.5	8.4	14.1	18.5	4.4	39.2	CL
Perpetua Beach											
A12	10.0	1.1	3.0	5.3	17.1	8.2	14.7	18.0	7.7	24.9	L
B2	7.7	0.8	2.6	4.9	14.8	10.6	10.3	20.6	9.6	25.8	L
Hembre											
A1	4.6	7.1	8.0	3.6	5.3	8.3	14.1	15.4	5.6	32.6	CL
A3	7.1	9.0	8.7	3.7	5.1	8.2	14.5	14.7	5.2	30.9	CL
B21	4.3	5.9	9.2	4.5	10.5	8.4	14.9	13.3	5.2	28.1	CL
Cascade Head											
A11	9.9	1.3	3.2	1.2	2.7	5.6	12.6	25.5	12.5	35.4	SiCL
A12	12.7	1.4	1.9	1.3	3.1	6.0	16.4	24.5	9.2	36.2	SiCL

Table 6. continued

Soil and Horizon	Gr. >2.0	V.C.S. 2-1	C.S. 1-.5	M.S. .5-.25	F.S. .25-.1	V.F.S. .1-.05	C.Si. .05-.02	M.Si. .02-.005	F.Si. .005-.002	C <.002	Texture
	mm				mm			mm		mm	
Tillamook Head											
A(CT-4)	15.3	1.3	1.1	0.8	1.9	2.6	7.2	20.9	14.0	50.2	SiC
A(CT-5)	16.4	1.4	1.4	1.2	2.7	3.4	10.1	26.0	10.6	43.2	SiC
Mulkey											
A11	27.3	1.0	6.2	6.2	11.7	16.5	18.3	21.0	5.6	13.5	L
A12	14.7	0.8	5.0	5.6	12.0	16.9	18.0	21.9	6.0	13.8	L
Quillayute											
A11	30.2	2.5	3.4	2.3	5.2	11.9	18.0	16.7	8.2	31.8	CL
A12	9.4	1.3	1.8	1.7	4.7	11.0	21.4	17.6	8.7	31.8	CL
A13	6.9	0.7	1.5	1.7	4.4	10.7	19.4	20.0	8.2	33.4	CL
Camas Prairie											
A	0.5	0.1	0.2	0.3	1.2	2.6	6.3	16.0	10.3	63.0	C
C	6.8	0.2	0.6	0.4	1.6	2.7	3.4	11.7	10.6	68.8	C
Camas Ridge											
A11	7.8	0.6	0.9	0.7	2.3	3.4	3.2	13.7	12.3	62.9	C
A12	7.3	0.1	0.2	0.2	1.0	3.2	7.8	6.8	18.8	61.9	C
Molock Beach											
A1	2.5	0.8	1.1	6.6	11.6	9.5	12.6	17.9	7.1	32.8	CL
AC	2.5	0.1	0.6	7.7	11.3	8.1	15.4	17.6	7.7	31.5	CL
C1	1.1	0.1	0.4	5.9	9.3	9.1	10.4	19.7	8.6	36.5	CL
Molock Creek											
A1	7.2	0.1	0.4	1.0	12.5	17.0	10.8	13.7	6.8	37.7	CL
AC	1.7	0.1	0.3	0.7	8.4	12.1	12.8	14.3	7.3	44.0	C

Mineralogy of the Sand and Silt Fractions

Sand and Silt Optical Identification Criteria

Many optical mineralogy texts are available describing criteria and methods of identification of the various minerals in rocks and sediments (Winchell, 1937; Kerr, 1959; Krumbein and Pettijohn, 1938; Milner, 1962). Recent publications pertinent to criteria for identifying soil minerals are Brewer (1964) and Cady (1965).

Refractive index (R.I.), relief, birefringence, color, pleochroism, shape, cleavage, crystal form, extinction angle, character of extinction, optic sign, optic angle and sign of elongation are all useful techniques for identifying relatively unweathered minerals. When fine-grained weathering products have partially or completely replaced the original mineral, optical techniques become less positive and less useful. In many of the soils studied rock fragments, minerals and/or mineraloids were weathered too extensively for recognition by optical techniques. X-ray diffraction was employed as much as possible to further characterize the weathering products. X-ray identification criteria for ground sand-sized fractions are essentially the same as that described on p. 86.

In addition to identification and frequency distribution, evidence of wear, abrasion, and relative alteration were noted during

petrographic study for the purpose of determining provenance differences (Pettijohn, 1957).

Rock and Saprolite Thin Sections

Price Peak. Examination of thin sections made from coarse saprolite fragments from the Price Peak sample site revealed a relatively high degree of rock weathering. The rock was a medium-grained aphanitic with an ophitic texture. The plagioclase feldspar was highly weathered and could not be identified petrographically. Feldspar grains were found in the sand fraction of the soil with a R.I. greater than 1.56 which would indicate that the feldspar composition was labradorite. In general, the pyroxene in the thin sections, identified as augite, was less weathered than the feldspar. Chlorophaeite was noted in the thin sections. Olivine was identified in one thin section. Although the plagioclase feldspar could not be definitely identified in the thin sections, it is probable that the rock was a basalt.

Yaquina Head. Most of the rocks in the Yaquina Head profile were highly weathered. However, a few little-weathered rock fragments were found in the lower horizon. A thin section of the little-weathered rock revealed scattered plagioclase feldspar, pyroxene and olivine phenocrysts in a groundmass of devitrified black glass. The feldspar was labradorite and the pyroxene was augite. Thus,

the rock appears to be a devitrified basaltic vitrophyre. Chloro-
phaeite was abundant in the thin section. A minimum of crystals or
crystal relics were observed in other more weathered saprolite
fragments which were examined. Thus, the more weathered rock
appeared to have the same origin as the less weathered rock.

Perpetua Head. Several little-weathered rock samples were
found in the Perpetua Head soil profile. Plagioclase feldspar and
pyroxene phenocrysts, some as large as 3 mm in length or diameter,
were included in an inequigranular-textured but generally very fine
grained aphanitic groundmass. The feldspar in the phenocrysts was
identified as labradorite. Although the rock was crystalline for the
most part, it appeared to contain some zones with a black devitrified
glass matrix. One thin section contained almost no large phenocrysts
and had more devitrified glass matrix. However, the porphyritic
basalt appeared to be more representative of the weathered parent
rock in the soil. Chlorophaeite was also noted in these thin sections.

Light Fraction Mineralogy

The fine sand, very fine sand, and coarse silt grain assem-
blage and frequency distribution in the light and heavy fractions of
each soil are located in Appendix III in Tables 3b through 3n. In this
study the light fraction consists of minerals with a specific gravity of
less than 1.85 as separated with bromoform.

Altered rocks, minerals, and mineraloids. In all of the soils studied it was found that many rock, mineral, and/or mineraloid grains were weathered and/or abraded too extensively for precise mineral recognition by optical techniques. These altered or weathered products varied from isotropic and translucent grains to opaque grains.

The distribution of the optically-unidentifiable grains in the light fractions is shown in Figure 4 as an average count percentage of the soil horizons sampled. In general, the non-recognizable grain content increased as the grain size increased. Weathered aphanitic volcanic rock fragments accounted for most of the optically unidentifiable grains in the Price Peak, Yaquina Head, Perpetua Head, Perpetua Beach, Hembre, and Cascade Head soils. After receiving several treatments for Fe removal, many of the difficulty-identifiable grains assumed a greenish color in transmitted and reflected light. Brown to reddish-brown shades were prominent, also. The refractive index of these altered grains varied from about 1.55 to 1.59. Based upon optical properties, the grains most closely resembled chlorite.

An example of x-ray diffraction patterns obtained from finely ground very coarse sand grains and fine sand and very fine sand fractions of the Hembre soil is shown in Figure 5. The approximate 13.5 Å peak maxima from Na-saturated samples (sample relative
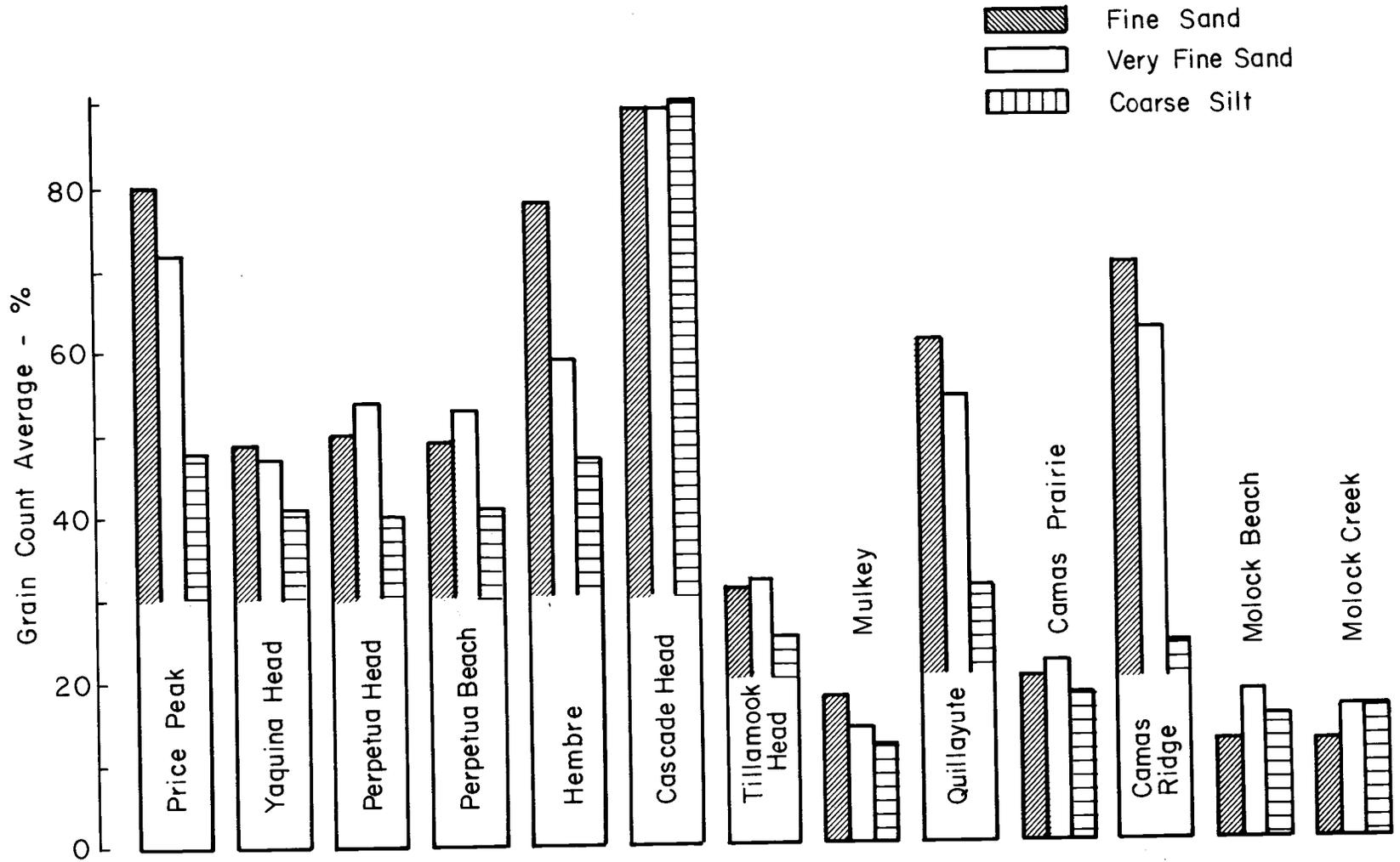
Figure 4. Petrographically non-recognizable grain averages of soil horizons sampled.
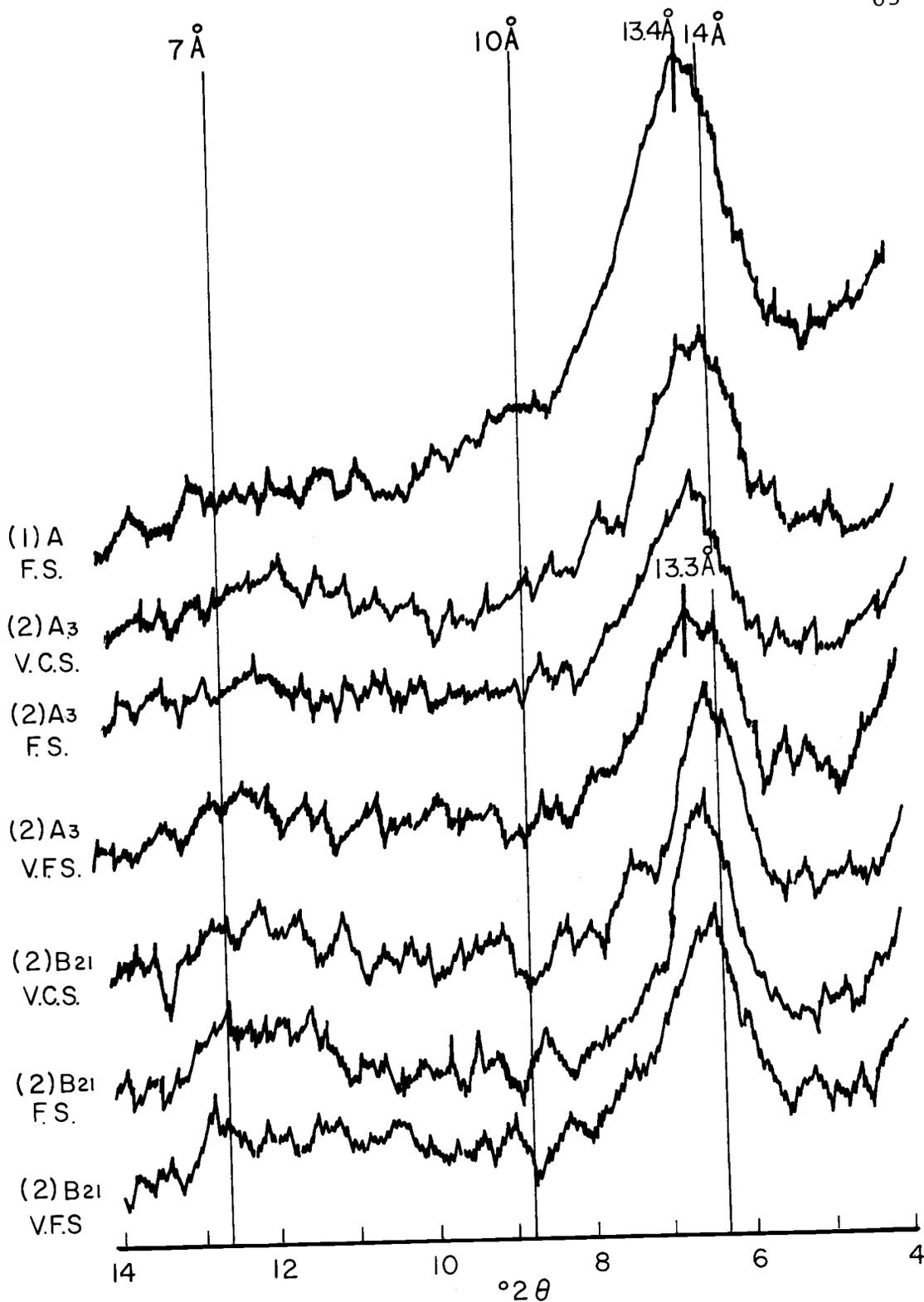
Figure 5. X-ray diffraction patterns of crushed Na-saturated sands from: (1) Singleton's Hembre A; and (2) Hembre A3 and B21 horizons.

humidity not controlled) indicates that the volcanic rock has largely weathered to a 2:1 layer type clay mineral. The lack of a prominent 7 $\overset{o}{A}$ or a completely consistent 14 $\overset{o}{A}$ peak indicates that chlorite is not an abundant weathering product in the sand fractions. X-ray diffraction patterns of crushed sand grains from the other soils assumed to have formed principally from basaltic rock are shown in Appendix VI (Figures 1a through 1 g). A clay mineral or minerals appears to be a very significant weathering product in each case.

Sand grains, such as the preceding, appear to have been incorrectly identified in a previous study (Singleton, 1966). The mineralogy of the Hembre A horizon samples studied by Singleton (1966, p. 70) was compared with that of the samples used in this study. In Singleton's samples 34% chlorite and 44% "altered brown glass", altering to chlorite, was reported. The x-ray diffraction patterns of the fine sands and very fine sands of the samples from both studies show remarkable similarity (Figure 5). The samples from Singleton's study produced the greatest peak intensity. The R.I. of the weathered grains in Singleton's Hembre sample, which apparently were counted as "altered brown glass" was in the range of 1.58-1.60, thus indicating basaltic glass. However, these grains showed much more birefringence than would be expected even for an altered basaltic glass. Many grains appeared to be vesicular which may have obscured the identification of these grains in Singleton's samples.

Clay mineral was a prominent constituent in the Quillayute sand

fractions (Appendix VI, Figure 1f). Weathered aphanitic and

phaneritic rock fragments made up a major proportion of the alluvi-

ally derived very coarse, coarse, and medium sand fractions.

Optically non-recognizable grains composed only a relatively small

fraction of the Mulkey soil which was formed from a contact meta-

morphic rock. The optically non-recognizable grains in the Camas

Prairie and Camas Ridge soils were sedimentary in origin. The

grains varied in color. Most grains were greenish but reddish

(hematite-stained), black, and white colored grains were present,

also. The composition of these grains, as determined by x-ray dif-

fraction, was mainly silt- or clay-sized quartz mixed with clay. The

optically non-recognizable grain content of the Molock Beach and

Molock Creek samples was relatively small. X-ray diffraction

patterns of sands from these soils indicated a small clay content.

Feldspars. The distribution of feldspars in the light fraction

of the soils is shown in Figure 6 as an average count percentage of

the horizons sampled. In general, the feldspar composition varied

in each soil. The feldspar type and composition was estimated mainly

by R.I. measurements. In several soils glass coatings on feldspars

hindered feldspar identification.

The feldspars in the Price Peak soil were, in order of apparent

decreasing frequency: oligoclase, andesine, and labradorite. About
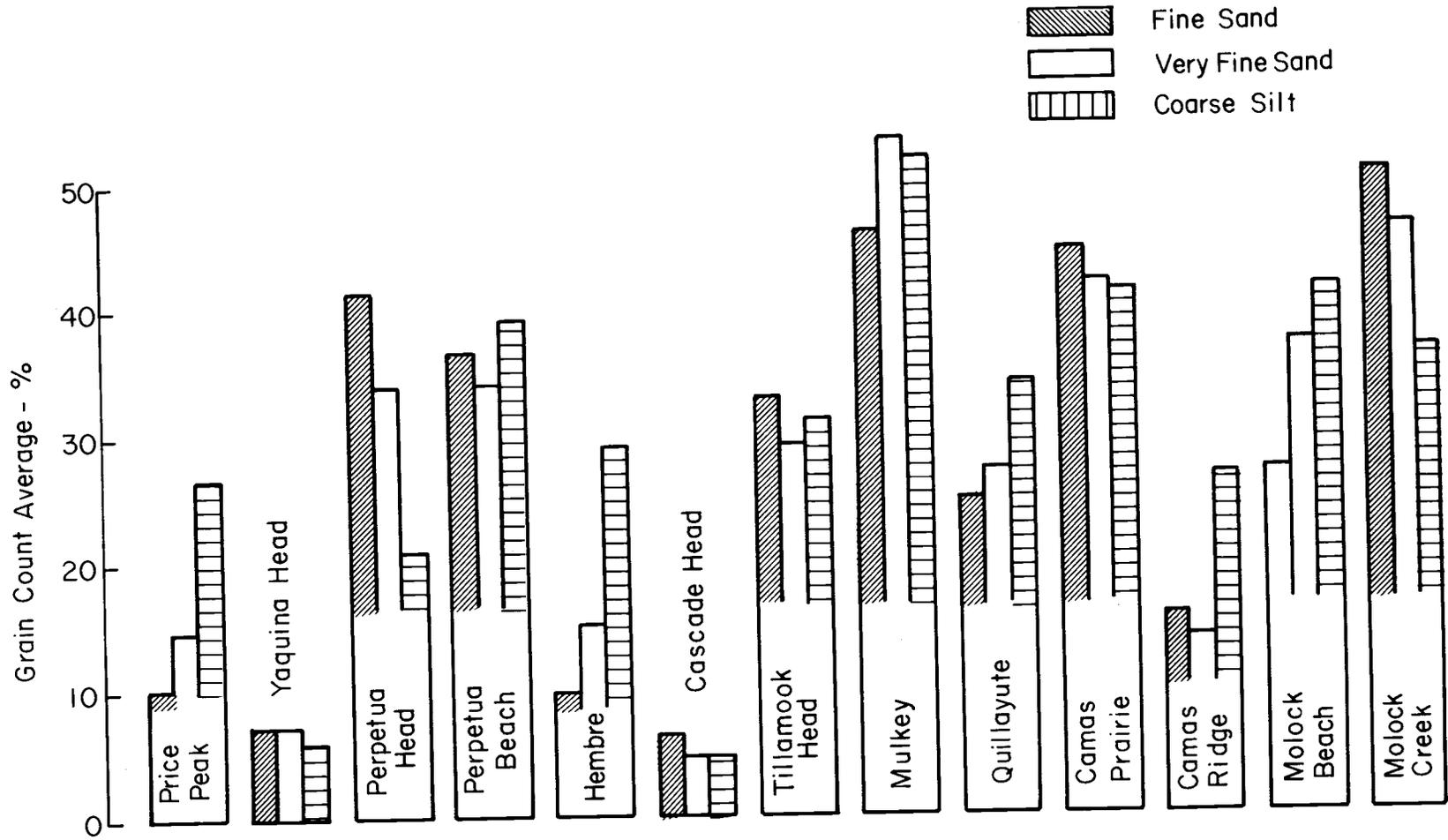
Figure 6. Feldspar grain averages of soil horizons sampled.

half the feldspars in the fine sand fraction were coated with glass,
indicating a volcanic ash origin.

Feldspars indicated by R.I. measurements in the Yaquina Head
grains were: andesine, oligoclase, albite, labradorite, orthoclase,
and microcline. Rounding and cloudiness of the feldspar grains
indicated that most, if not all, originated from eolian deposits of
beach sand.

The predominate feldspar in the Perpetua Head and Perpetua
Beach soils was labradorite. The high degree of angularity of these
grains indicates that their origin was the feldspar phenocrysts from
the porphrytic basalt. More rounded feldspar grains indicated minor
eolian deposits in the Perpetua Head soil and substantial eolian de-
posits in the Perpetua Beach soil. The feldspars in the eolian de-
posits were variable in type and composition.

The predominate feldspar in the Hembre and Cascade Head
soils was oligoclase. At least a part of this was from a volcanic ash
deposit. An eolian deposit was indicated by grain abrasion and round-
ing in the Cascade Head soil. The mineral suite for the Mulkey soil
closely matched the description given for the granophyric diorite by
Roberts (1953) except for the feldspar which was reported to be
andesine. The R.I. index of the feldspar grains in the Mulkey indi-
cated an oligoclase composition.

Except for minor variations, the feldspar suite was the same

for the Tillamook Head, Quillayute, Camas Prairie, Camas Ridge,

Molock Beach, and Molock Creek. Oligoclase tended to be the pre-

dominate plagioclase feldspar. Albite, orthoclase, and microcline

were present, also. Orthoclase and microcline composed a signifi-

cant proportion of the feldspars in the Molock Creek and Molock

Beach soils.

Quartz. The quartz distribution in the soil light fractions is

shown in Figure 7. The quartz found in the soils primarily derived

from the basaltic rocks (Price Peak, Yaquina Head, Perpetua Head,

Perpetua Beach, Hembre, and Cascade Head) apparently originated

from eolian deposits or possibly in volcanic ash deposits. In this

group of soils, quartz was a major constituent in only the Yaquina

Head soil where a recent deposition of beach sand was readily

apparent. In the case of the Mulkey soil quartz was a mineral of the

parent rock.

Quartz was a major constituent in soils derived from sediments

or sedimentary rock (Tillamook Head, Camas Prairie, Molock

Beach, and Molock Creek). The source of the quartz in the Quillay-

ute alluvium cannot be ascertained.

Volcanic glass and palagonite. Volcanic glass was found in

every soil in the study. The distribution in the soils is shown in

Figure 8. The R.I. of most of the glass shards fell closely in the
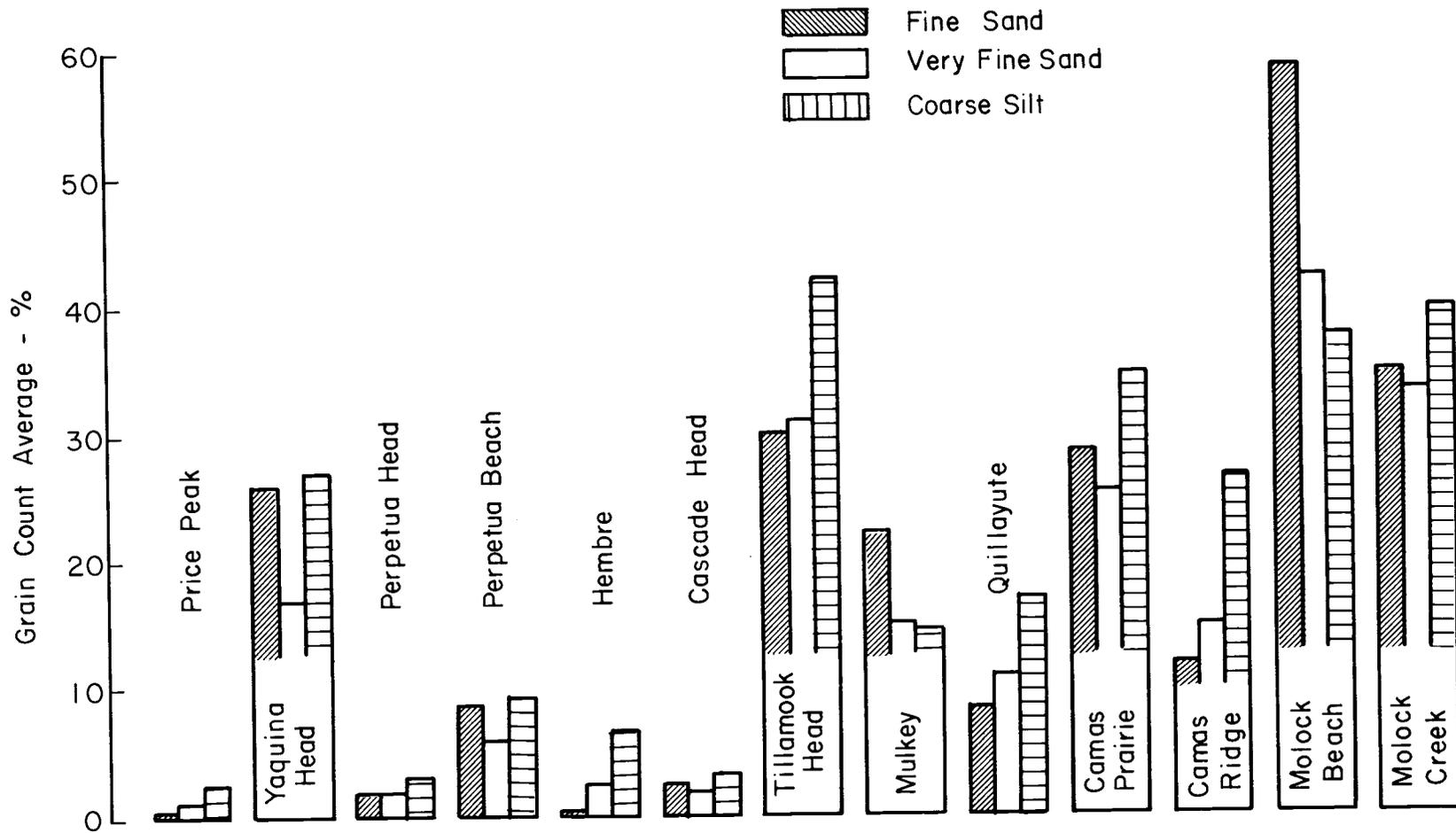
Figure 7. Quartz grain averages of soil horizons sampled.
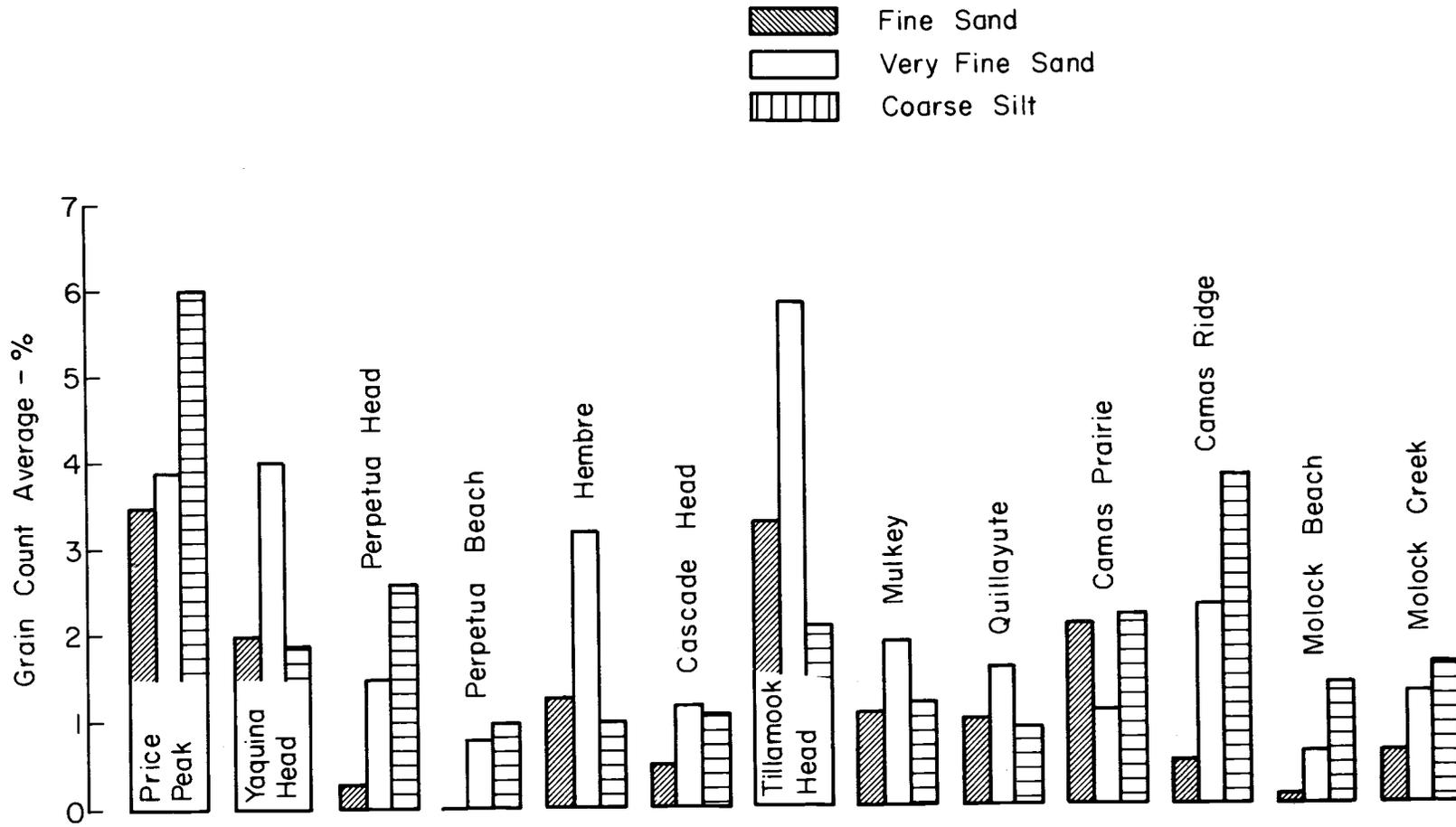
Figure 8. Volcanic glass averages of soil horizons sampled.

range of 1.50 to 1.51. This fits the range of Mt. Mazama dacitic

glass (1.500-1.510) given by Powers and Wilcox (1964). Plagioclase,

hornblende, hypersthene, and small amounts of augite were reported

to be components of the Mt. Mazama ash. Euhedral hypersthene and

hornblende phenocrysts with glass sheaths or the remains of a

sheath were found in the heavy fraction of nearly all the soils. Thus,

it was concluded that the dacitic glass in the soils originated from

Mt. Mazama for the most part. However, some of the glass shards

in two soils, the Tillamook Head and Molock Creek, had a R.I. lower

than 1.50. The R.I. of these shards was between 1.49 and 1.50. It

is possible that the glass was a part of the sedimentary rock from

which the soil was formed. Glacier Peak, a volcanic peak closer to

Tillamook Head than Mt. Mazama from which a relatively recent

eruption took place, is a possible source of this glass with a lower

R.I. The R.I. of the Glacier Peak glass is 1.495 to 1.500 according

to Powers and Wilcox (1964). It was reported that no clino-pyroxene

was present in the Glacier Peak ash. A small number of glass-

covered euhedral augite phenocrysts were located in the Tillamook

Head heavy fraction, indicating at least part of the glass originated

from Mt. Mazama.

In addition to about 0.3% to 0.9% dacitic glass shards, a glass

with a R.I. between 1.58 and 1.59 was found in the Yaquina Head

soil. The R.I. measurement indicate a basaltic glass. In contrast

to the black glassy matrix in the thin section, the grains were green to dark brown in transmitted light. The color difference between the thin section matrix and the grains might have been due to iron-removal treatments on the soil samples. Conchoidal fracture was observed in many grains and flow structure was observed occasionally. The basaltic glass was largely altered to palagonite. For counting purposes the glass and palagonite were differentiated on the amount of birefringence of the grain and the cloudiness in reflected light. When the mineraloid was completely isotropic, except for occasional phenocryst inclusions, and showed little or no cloudiness, it was counted as glass. The grain was counted as palagonite if some birefringence or cloudiness occurred. The basaltic glass content varied from about 1% to 5%. The palagonite content averaged about 8% for the three separate sizes in all horizons (Appendix Table 3c).

Palagonite similar to that in the Yaquina Head was found in the Cascade Heal soil. However, grain roundness indicated that the palagonite in the Cascade Head originated from an eolian deposit.

Plant Opal. Plant opal, an amorphous hydrated silica of organic origin was found in every soil studied and it was abundant in a few soils. Grass appears to be the most prolific producer of "opal phytoliths" by precipitating silica within the epidermal leaf cells to form objects with characteristic shapes and sizes (Beavers and Stephan, 1958). Douglas fir produces an opal phytolith which differs

in appearance from grass opal (Brydon, et al., 1963) and thus can be readily identified.

The opal distribution in the coarse silt fraction of the soils is shown in Figure 9. In general, the opal content decreased with soil depth. In some cases variation in the opal content-depth relationships were caused by profile discontinuities (Yaquina Head, Quillayute). In other cases, colluvial activity apparently has resulted in opal accumulation in the deeper soil horizons (Perpetua Head, Camas Ridge).

The highest soil plant opal contents were found in soils with some relatively unweathered rock still in the profile (Price Peak, Yaquina Head, and Perpetua Head). The opal content in the Perpetua Head soil is extremely high. The plant opal found in the fine and very fine sands (Appendix Tables 3a through 3n) mainly appeared to originate from conifers.

Abundant plant opal in soil appears to be indicative of a rapid weathering environment in which much Si in solution is being taken up by plants. Removal of this Si from the soil solution would retard the formation of pedogenic clay.

Zeolite, mica, and carbonaceous material. Zeolite, mica, and carbonaceous material occurrence and distribution in the light fraction of the soils are shown in Figure 10.
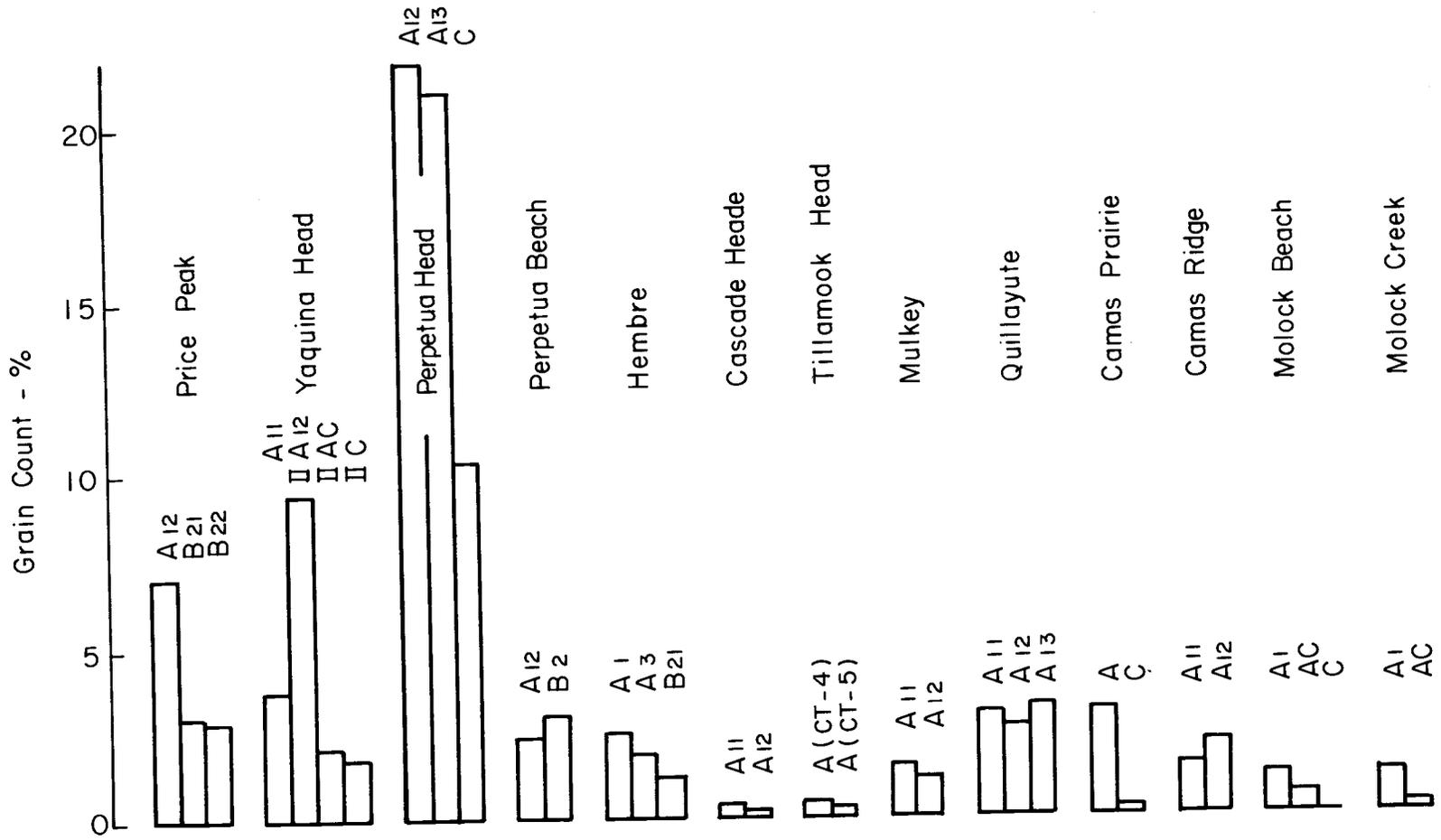
Figure 9. Plant opal contents in the coarse silt fractions.
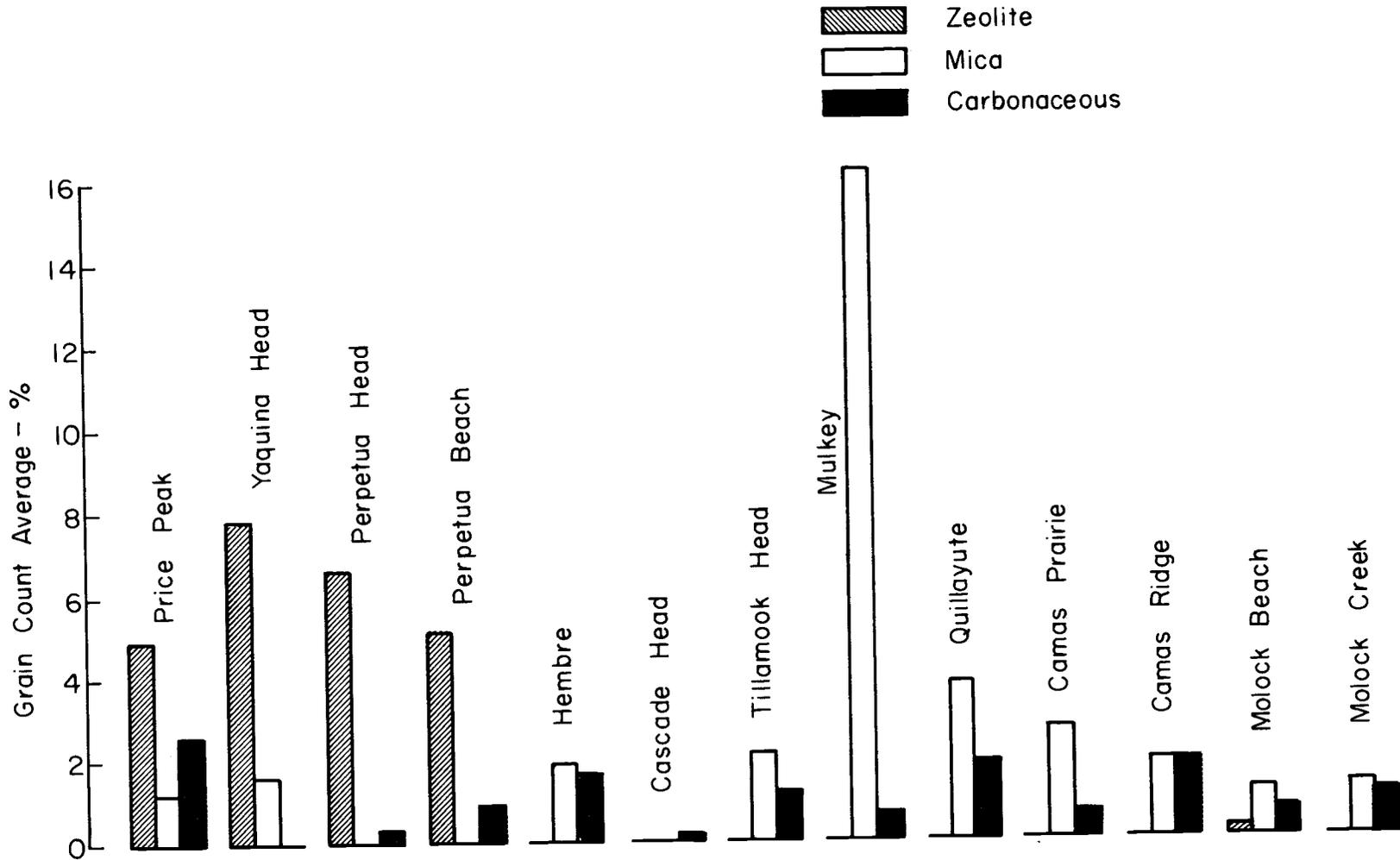
Figure 10. Zeolite, mica, and carbonaceous material grain averages of sands and silt and soil horizons sampled.

Zeolites occurred in five soils, mainly in those formed pre-
dominately from basaltic rock. Minor amounts of zeolite were found
in the Molock Beach soil but these may have originated from eolian
deposits. For the most part, specific zeolite minerals were difficult
to identify and differentiate in the soils. Some of the zeolite sepa-
rated in the Price Peak soil was identified as heulandite. This
occurred as a distinct tabular, biaxially positive crystal with a R.I.
of 1.49 to 1.50 and with a 2V of 40° to 45°. A prominent acicular
zeolite in the Yaquina Head soil was identified as natrolite. Other
zeolite minerals probably occurred but positive identification was not
made because good interference figures were not found and precise
R.I. measurements were difficult to make. Stilbite was tentatively
identified in the Perpetua Head soil on the basis of a tapered crystal
shape, biaxially negative interference figure, and a R.I. between
1.49 and 1.50.

Mica occurred in either the light fraction or heavy fraction of
all the soils studied. The Cascade Head soil formed from volcanic
rock contained the least total mica and the Mulkey soil formed from
a granophyric diorite contained the most (Figure 10). Biotite or
bleached biotite was the most common mica in the soils formed
mainly from basaltic rock and the granophyric diorite. Muscovite
was more prevalent than biotite in the soils of alluvial and sedi-
mentary rock origin.

Charcoal, a non-mineral substance, was found in nearly every soil studied. It occurred predominately in the coarser sand separates but it was also a minor constituent in the fine and very fine sand and coarse silt fractions (Figure 10). A gradation in the hardness of the charcoal (carbonaceous material) was observed especially in the coarser sand fractions. Some fragments could be crushed easily with a probe while others strongly resisted. It appears that the charcoal undergoes mineral impregnation in the soil. Because of the widespread occurrence of the substance in the soils, tests were made to verify this observation. Upon heating these mineralized fragments, the black color disappeared leaving an opaque white residue. Silicon was identified in the residue. Mineralization of the charcoal produced a very hard substance with a black metallic luster and a clinker-like appearance. A photograph of the very coarse sand-sized siliceous charcoal is shown in Figure 11.

Amygdules. Speroidal-shaped amygdules were found in amounts varying from about 1% to 15% of the grain count in the Yaquina Head, Perpetua Head, Hembre, and Quillayute soils. These probably originated in gas vesicles in basaltic rock.

Heavy Fraction Mineralogy

Heavy mineral fractions in the sand and silt separates of the soils varied from 2% (Hembre and Camas Prairie) to 64% (Mulkey) by weight (Appendix III, Tables 3a through 3n).
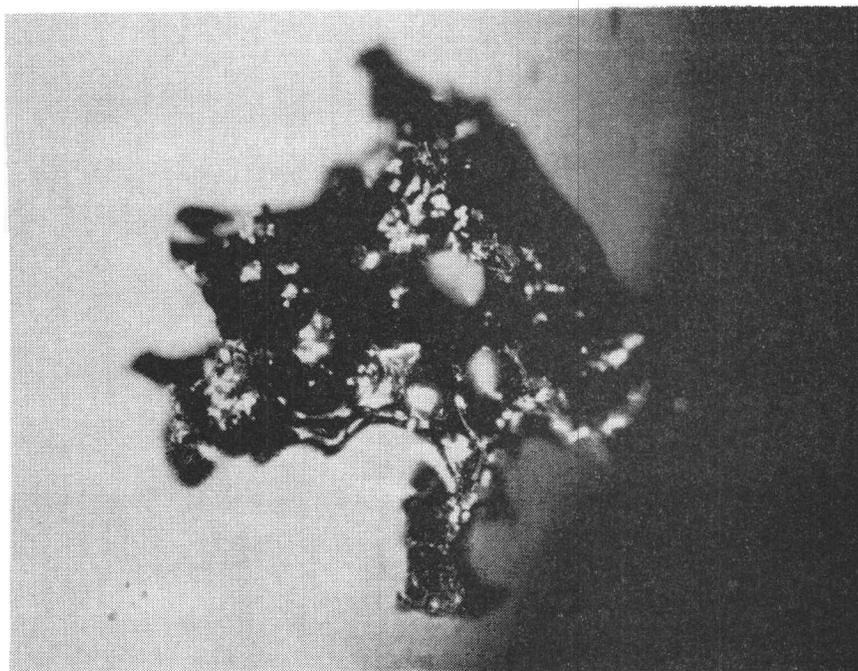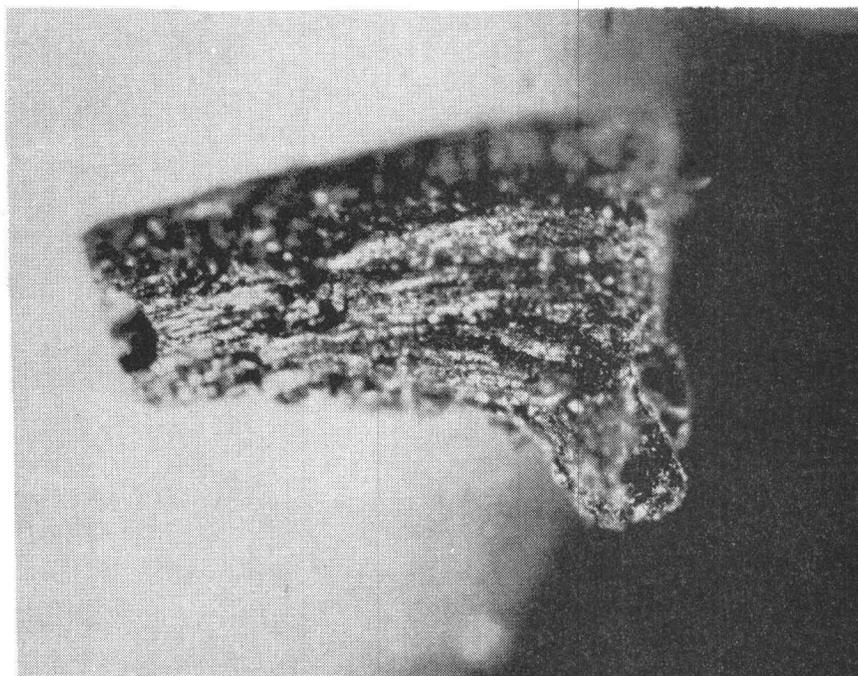
Figure 11. Charcoal (top) and mineral-impregnated char-
coal showing holes and conchoidal surface
(bottom).

Clino-pyroxene, hypersthene, and amphibole. The clino-pyroxene, hypersthene, and amphibole distribution in the soils is shown in Figure 12. Augite was the most common clino-pyroxene identified in most of the soils, especially those formed from basaltic rock. A light-green colored clino-pyroxene occurring in the Quillayute soil was identified as pigeonite since it was optically positive with a very small optic axial angle.

Some hypersthene appeared to be derived from the Mt. Mazama ash deposit. This was found as euhedral phenocrysts often with a coating of glass. Magnetite inclusions in the hypersthene were common. Hypersthene was also common in the eolian material deposited in soils near the coastal region.

Euhedral grains of hornblende found in the soils also appeared to be derived from the Mt. Mazama ash deposit. Amphibole (mainly hornblende) was common in the sedimentary material and eolian deposits. Hornblende was a major constituent in the granophyric diorite parent material of the Mulkey soil.

Magnetite and ilmenite. A complete separation of magnetic and non-magnetic heavy minerals was not achieved. If the hand magnet was held too close to the samples, it removed hypersthene in which magnetite was imbedded. The distribution, by weight, of magnetically-separated magnetite and the remaining ilmenite plus magnetite counted in the samples is shown in Figure 13. Magnetite
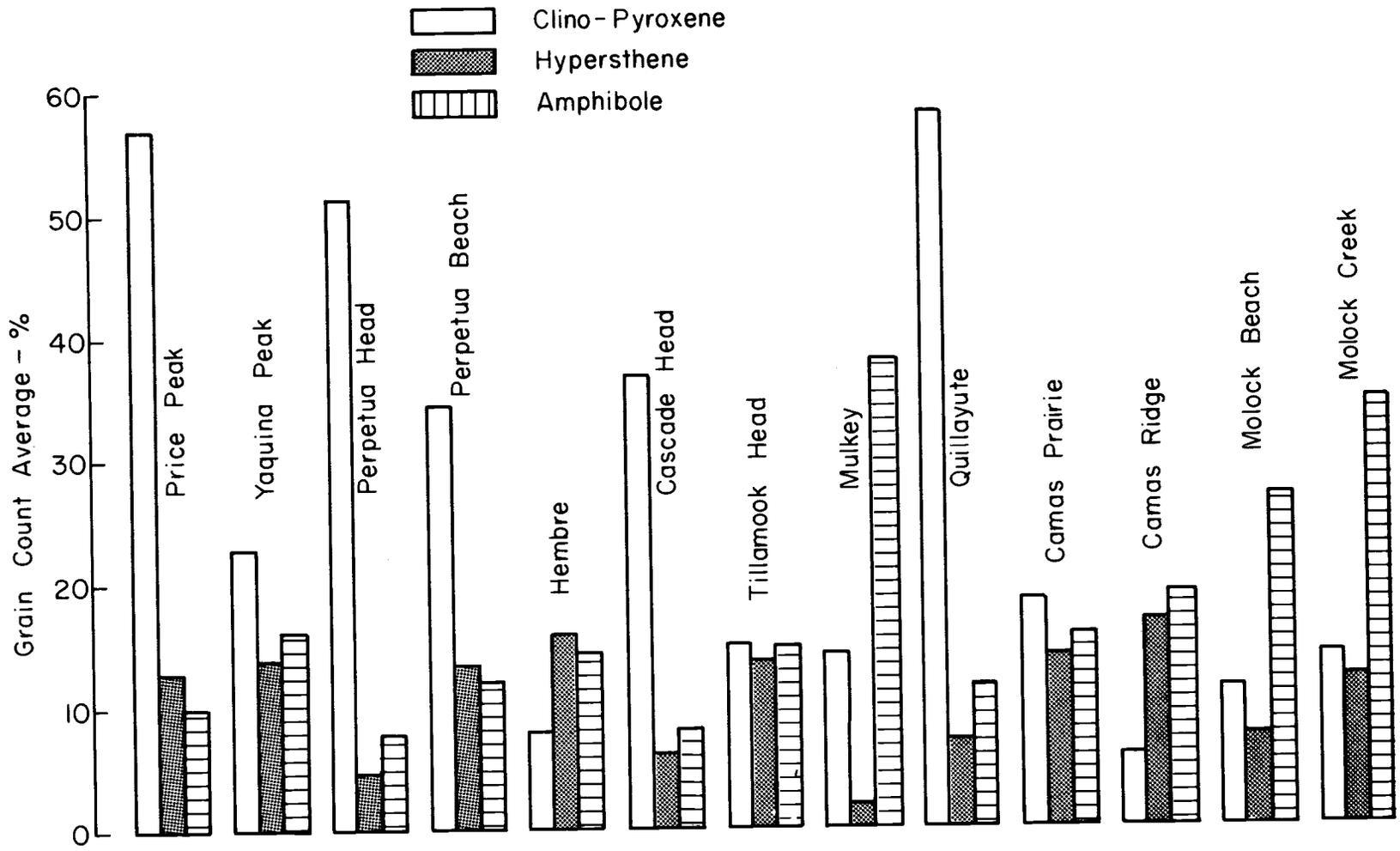
Figure 12. Pyroxene and amphibole grain averages of sands and silt and soil horizons sampled.
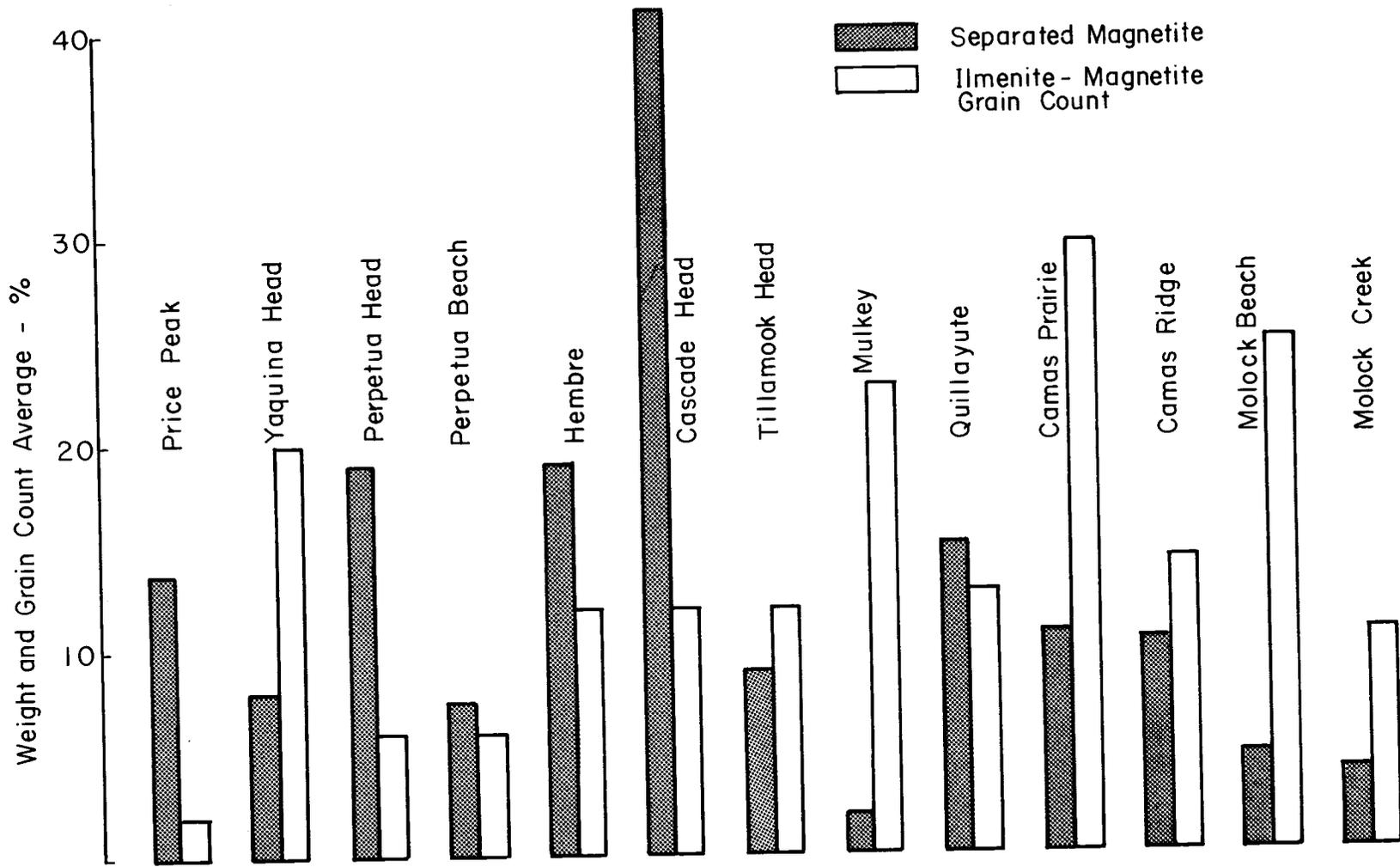
Figure 13. Magnetically-separated magnetite weight and ilmenite plus magnetite grain averages of sands and silt and soil horizons sampled.

was a major mineral in the Hembre and Cascade Head heavy frac-
tions. Since magnetite is relatively stable in the heavy mineral
weathering scale, the high magnetite content indicates a relatively
mature soil. Ilmenite was the predominant opaque mineral in the
Mulkey soil.

Hematite, zircon, and garnet. Hematite was a prominent
constituent in the Hembre, Tillamook Head, and Camas Ridge soils.
Zircon was found in every soil studied, especially in the coarse silt
fractions. Garnet was a relatively minor mineral in the sediments
or in soils derived from sedimentary rock immediately adjacent to
the Oregon Coast. Garnet was also a constituent mineral in eolian
deposits (Figure 14).

Kyanite, staurolite, epidote, clinozoisite, and iodocrase.
Minerals indicative of a high-temperature or high-pressure meta-
morphic origin were found in the Molock Beach and Molock Creek
soils. The total amounts of these heavy fraction minerals were
small averaging about 4% in the Molock Beach and 9% in the Molock
Creek samples. Small amounts of staurolite in both soils occurred
almost exclusively in the fine sand fraction. A small amount of a
bladed mineral, tentatively identified as iodocrase, was also noted in
the fine sand fractions of the Molock Creek samples. Kyanite was a
more prevalent metamorphic mineral especially in the fine and very
fine sand separates of both soils. The kyanite content increased as
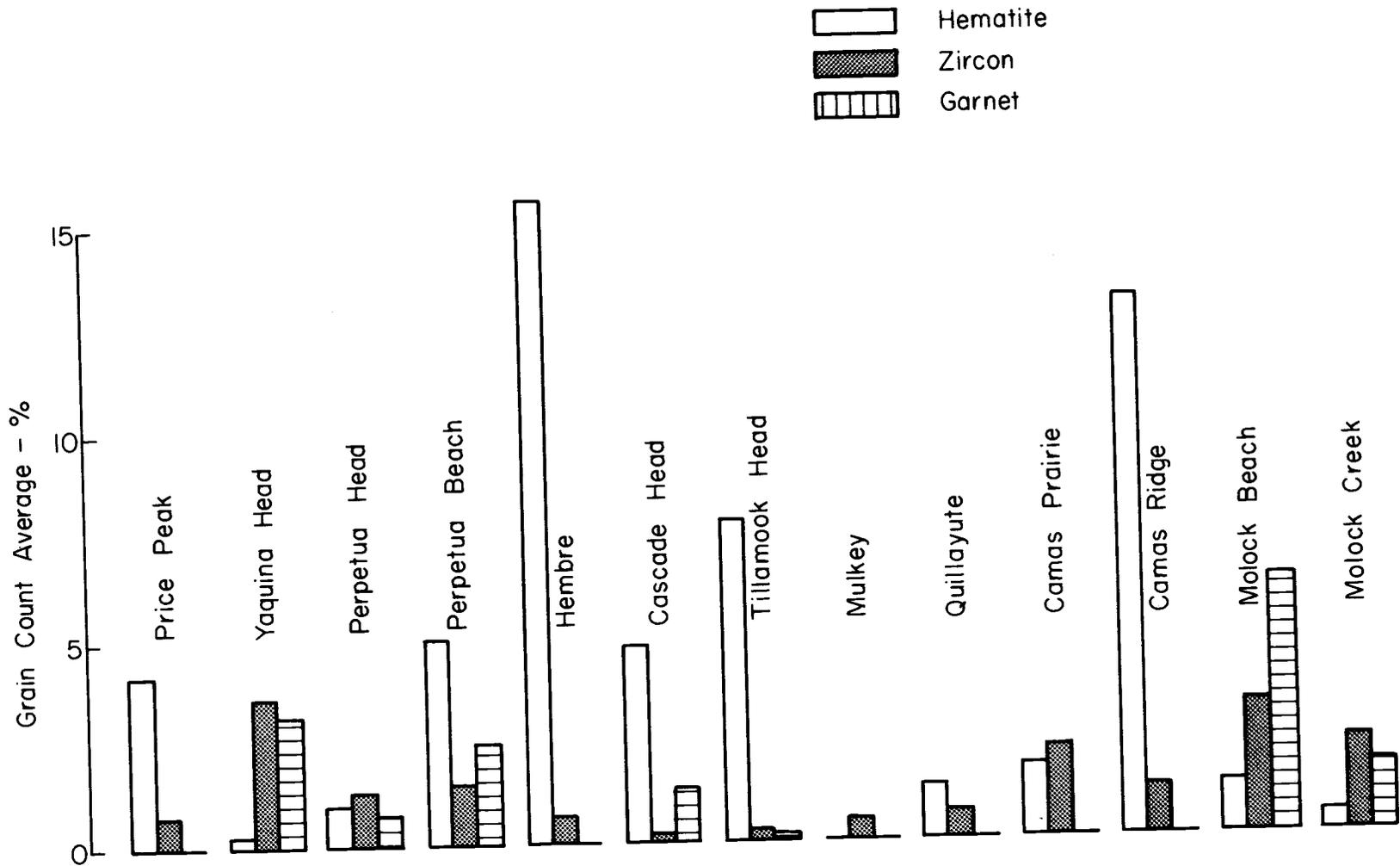
Figure 14. Hematite, zircon, and garnet grain averages of sands and silt and soil horizons sampled.

the size of the fraction decreased. Epidote and/or clinozoisite were found mainly in the very fine sand and coarse silt fractions.

Sphene. Small amounts of sphene were tentatively identified in the Camas Prairie silt fractions.

Mineralogy of the Clay-Sized Fractions

Clay-Sized Mineral Identification Criteria

Clay-sized mineral components in the samples were identified from x-ray analysis, D.T.A. analysis and the 0.5 $\underline{N}$ NaOH dissolution treatment results.

X-ray diffraction analysis. The general criteria used in this study for differentiating clay mineral species from basal (001) x-ray diffraction spacings are tabularized in Table 7. The term "smectite" is a group name for expanding-lattice phyllosilicate minerals which includes nontronite, beidellite and montmorillinite. The presence of amorphous components is suggested by a high background of the diffraction pattern and decreased resolution of peaks.

Random interstratification of two or more clay species within a crystal produces a d-spacing intermediate between that of the individual minerals. Regular stratification of two or more species produces a d-spacing which is the sum of the (001) of the individual minerals.

Differential thermal analysis. The literature and published D.T.A. curves of clay-sized minerals is voluminous. A major part of these publications deal with geologic specimens. It should be emphasized that D.T.A. curves of soil clays may differ considerably

Table 7. Approximate x-ray diffraction basal (001) spacing obtained with characterizing treatments of clay minerals.

Diffraction Spacing Å	Treatment and Mineral
	Mg-saturated, 54% relative humidity
14-15	Smectite, vermiculite, chlorite, chloritic intergrades
9.9-10.1	Mica (illite), hydrated halloysite
7.2-7.5	Metahalloysite
7.1-7.2	Kaolinite, chlorite (2nd order)
	Mg-saturated, solvated with ethylene glycol vapor
17-18	Smectite, some chloritic intergrades
14-15	Vermiculite, chlorite, some chloritic intergrades
	Mg-saturated, solvated with glycerol vapor
17-18	Montmorillinite, some chloritic intergrades
14-15	Vermiculite, chlorite, nontronite and beidellite (tetrahedrally substituted smectites), some chloritic intergrades
9.9-10.1	Mica (illite)
7.2-7.5	Metahalloysite
7.1-7.2	Kaolinite, chlorite (2nd order)
	K-saturated, 105° C heat, dry air
14-15	Chlorite, some chloritic intergrades
10-14.5	Chloritic intergrades (with OH-interlayer Fe or Al)
10-10.2	Smectite, vermiculite, mica (illite)
7.2-7.5	Metahalloysite
7.1-7.2	Kaolinite, chlorite (2nd order)
	K-saturated, 105° C heat, 54% relative humity
14-15	Chlorite
10.5-14	Chloritic intergrades
12-12.5	Smectite
10-10.4	Vermiculite, mica (illite)
7.2-7.5	Metahalloysite
7.1-7.2	Kaolinite, chlorite (2nd order)
	K-saturated, 300° C heat, dry air
14-14.5	Chlorite
9.9-10.2	Smectite, vermiculite, mica (illite)
7.2-7.3	Metahalloysite (collapsed)
7.1-7.2	Kaolinite, chlorite (2nd order)
	K-saturated, 500° C heat, dry air
14-14.5	Chlorite
10-14	Chloritic intergrade
9.9-10.1	Smectite, vermiculite, mica (illite)

from those of corresponding geologic specimens (Barshad, 1965).

D.T.A. curves and identification criteria for most of the clay

minerals found in soils are summarized by Jackson (1956, pp. 265-

269); Mackenzie (1957); Barshad (1965, pp. 712-720); and Grim (1968,

pp. 278-352). Some calibration and interpretation must be made for

individual D.T.A. units. Reaction peak height, temperature and

sometimes shape may vary with sample heating rate, sample size,

sample weight and degree of packing. The general D.T.A. criteria

used in this study are given in Table 8.

Effect of boiling NaOH dissolution. The boiling 0.5 $\underline{N}$ NaOH

treatment of Hashimoto and Jackson (1960) was intended to serve as

an estimate of the amount of amorphous components in the clay frac-

tion. The "amorphous" components are usually defined as those

which do not produce x-ray diffraction maxima. Boiling a clay for

2.5 min. in a large excess of 0.5 $\underline{N}$ NaOH causes dissolution of free

amorphous silica, free alumina and large percentages of amorphous

combined alumino-silicates, including allophane (Jackson, 1965b).

However, Jackson (1965) includes gibbsite, which is crystalline and

usually not amorphous to x-rays, in the "free" alumina group which

is dissolved. The boiling NaOH treatment removes at least a portion

of hydroxy-Al interlayer material from chloritic intergrade clays

(Singleton, 1965, p. 22; Tamura, 1956). The "free" Si dissolved

includes colloidal Si, opal and fine quartz (Jackson, 1956, p. 529).

Table 8. Approximate differential thermal analysis peak tempera-
tures for selected Ca-saturated soil minerals.

Mineral	Dehydration Endotherm $^{\circ}C$	Dehydroxylation Endotherm $^{\circ}C$	Recrystallization Exotherm $^{\circ}C$
Allophane, amorphous alumino-silicate material	100-180		800-950
Kaolinite	Absent	550-600	900-950
Metahalloysite	100-130	530-570	880-920
Nontronite	100-250 (Dbl.)[*]	500	850-1050
Beidellite	100-250 (Dbl.)	500-550	900-1050
Montmorillinite	100-250 (Dbl.)	750-925	900-1040
Gibbsite		300-330	

[*]Double peak

Jenne (1961, p. 74) reported 3-7% weight losses from reference clay minerals given the 2.5 min. boiling 0.5 $\underline{N}$ NaOH treatment. Poorly crystalline halloysite minerals are reported to be appreciably attacked by the 0.5 $\underline{N}$ NaOH (Jackson, 1965b, p. 591) and must be taken into consideration.

Thus, the treatment is not entirely selective for strictly amorphous materials. Any quantitative interpretation for amorphous material is subject to either establishing the absence of other crystalline components dissolved by the treatment or making a correction for them when present in the clay sample. Chemical analysis of the constituents dissolved during the boiling NaOH treatment provides additional information as to the character of the material dissolved.

Crystalline Components

The crystalline clay-sized components were identified primarily by x-ray diffraction analysis. Differential thermograms were used to corroborate the x-ray diffraction data in some cases. In other cases, the D.T.A. thermograms produced the stronger evidence of the presence of minerals, such as gibbsite and the kaolin group.

The amount of sample cleaning before x-ray diffraction analysis strongly affected the clarity and character of the x-ray diffraction maxima for the majority of the clays in the study. The resolution of diffraction maxima improved as the cleaning treatment went from one

whole-soil iron-removal treatment (Pretreatment I) to three whole-soil iron-removal treatments (Pretreatment II) through several iron-removal treatments later performed on Pretreatment I clays. Expansion and contraction tendencies of smectite or vermiculite components improved with the increased number of severity of each cleaning treatment through the boiling NaOH treatment of the clays. This improved expansion and contraction apparently was the result of more hydroxy-interlayer removal with progressive treatment numbers and severity.

Because of the rather large number of samples, only the x-ray diffraction data following the boiling NaOH treatment sequence of each sample are presented. These data are shown in the even-numbered figures 16 to 40 beginning on p. 92. Differential thermograms of the Ca-saturated samples which received only one whole-soil iron-removal (Pretreatment I) are presented in the odd-numbered figures 17 to 41 beginning on p. 93.

The x-ray diffraction data show a gross similarity of the mineral suites for the majority of the soils studied. However, the mineral suites indicated by the x-ray and D.T.A. data are quite complex. Further cleaning treatments followed by x-ray analysis and D.T.A. would have been helpful, but it was beyond the scope of the present work.
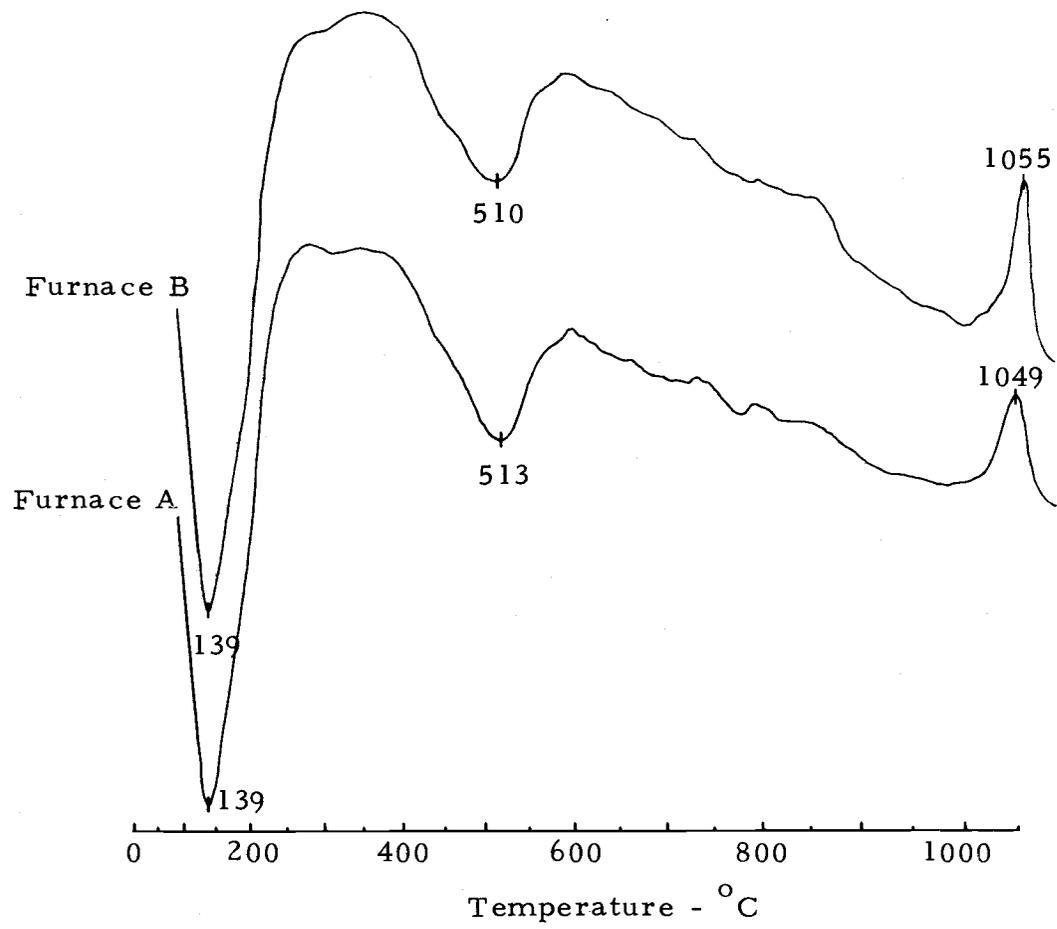
Figure 15. D.T.A. patterns of Ca-saturated Garfield, Wash. nontronite clay run with two different furnaces.
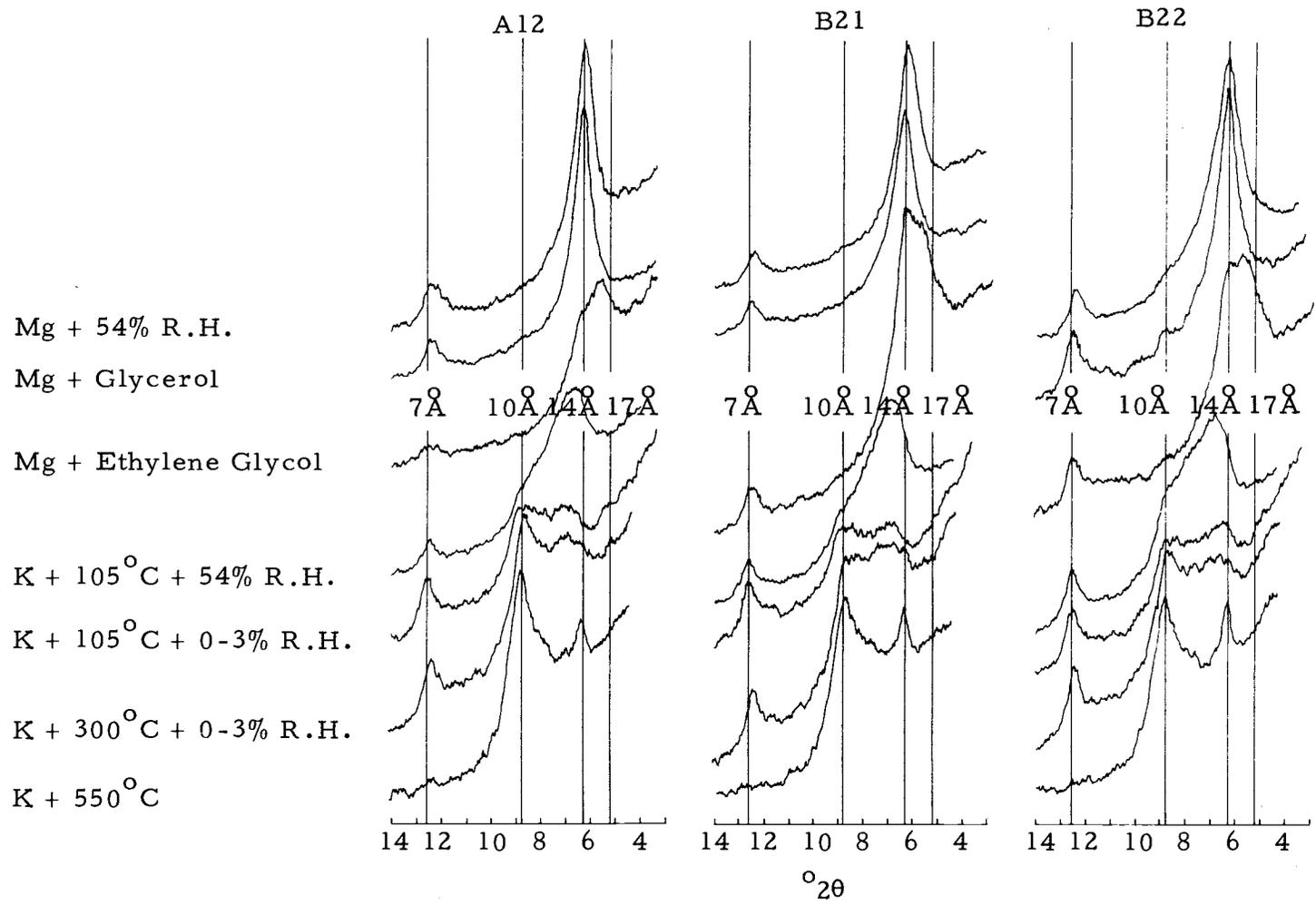
Figure 16. X-ray diffraction patterns of the Price Peak clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.
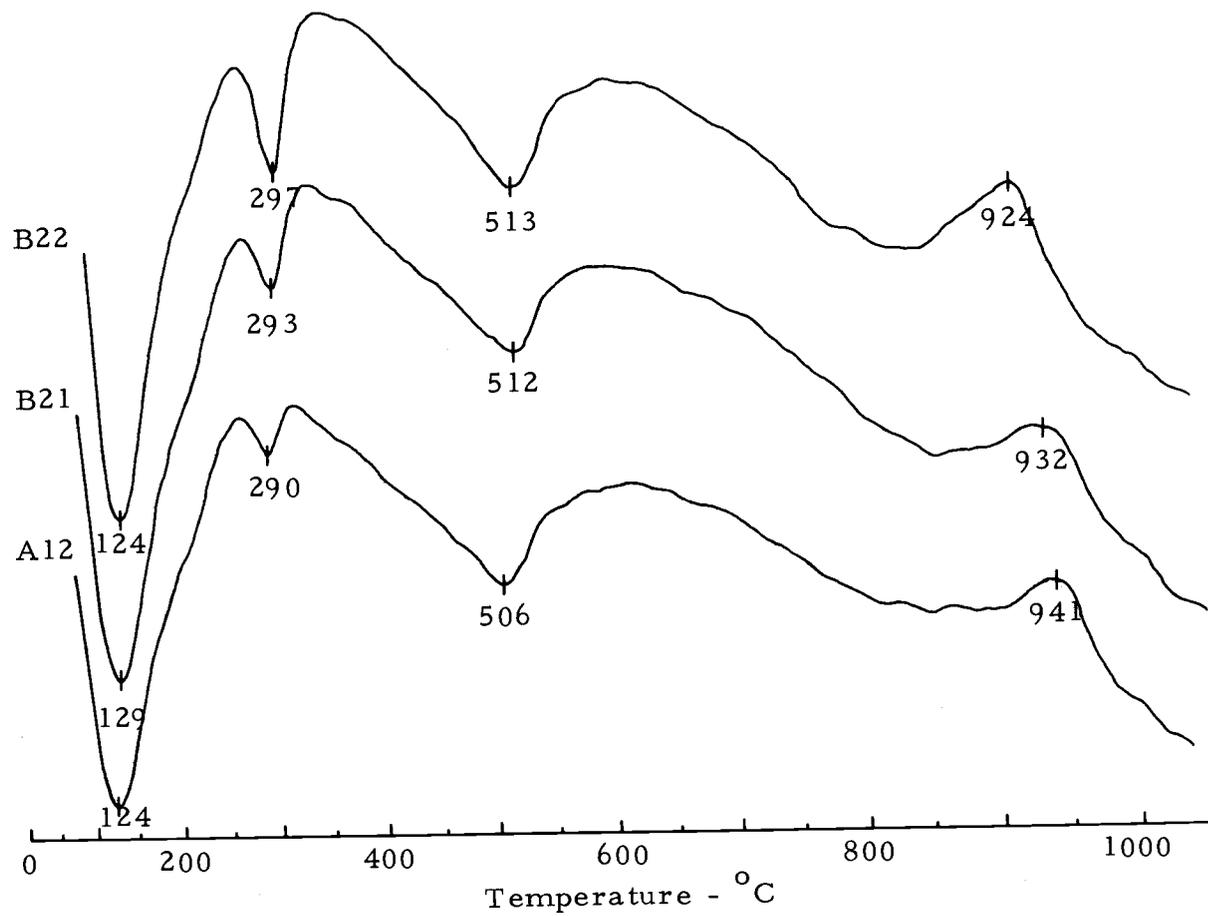
Figure 17. D.T.A. patterns of the Price Peak Ca-saturated clay samples (Pretreatment I).

A11 IIA12 IIAC IIC

Mg + 54% R.H.

Mg + Glycerol

Mg + Ethylene Glycol

7Å 10Å 14Å 17Å   7Å 10Å 14Å 17Å   7Å 10Å 14Å 17Å   7Å 10Å 14Å 17Å

K + 105°C + 54% R. H.
K + 105°C + 0-3% R.H.

K + 300°C + 0-3% R.H.

K + 550°C

14 12 10 8 6 4   14 12 10 8 6 4   14 12 10 8 6 4   14 12 10 8 6 4

°2θ
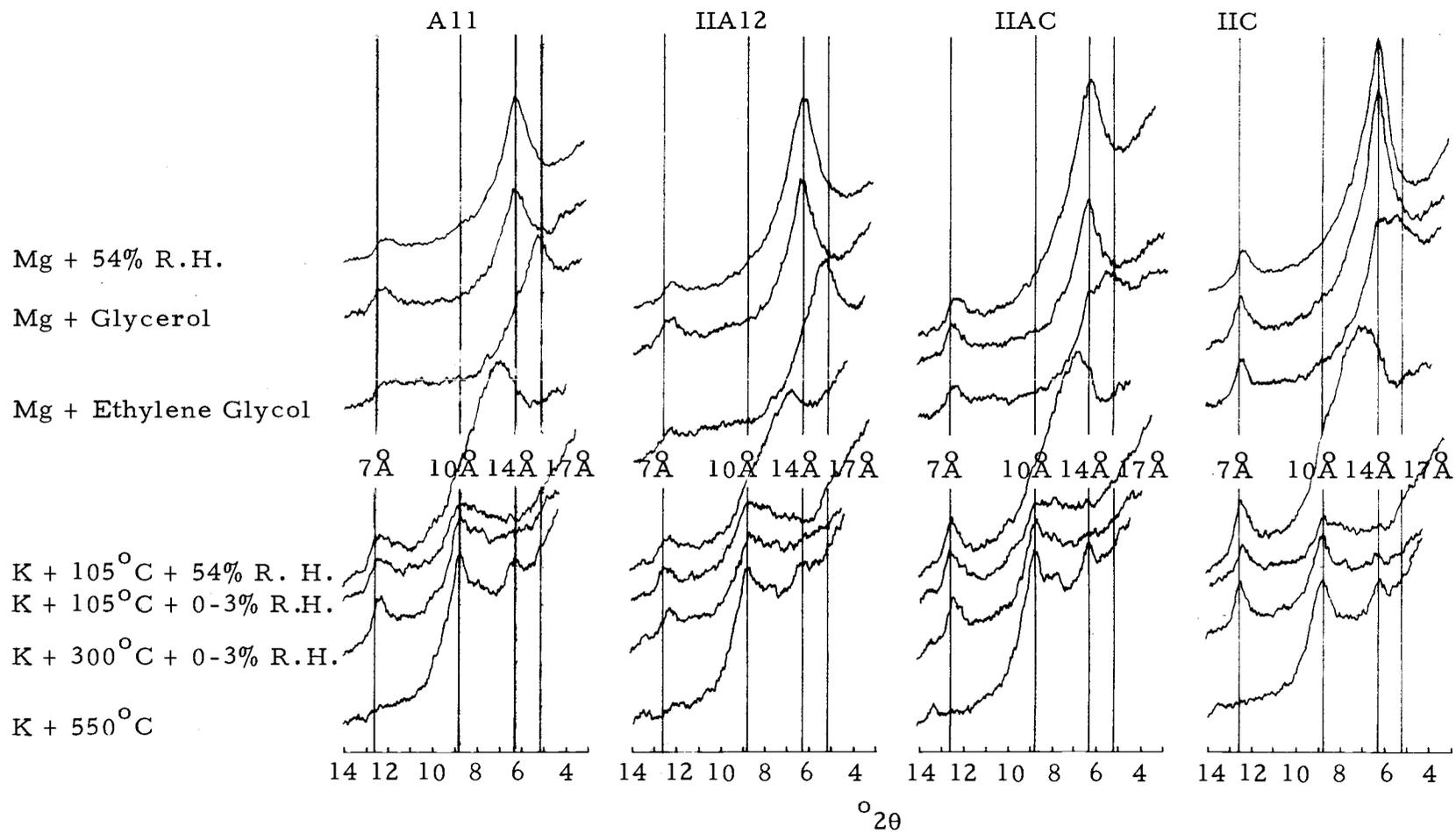
Figure 18. X-ray diffraction patterns of the Yaquina Head clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous material.
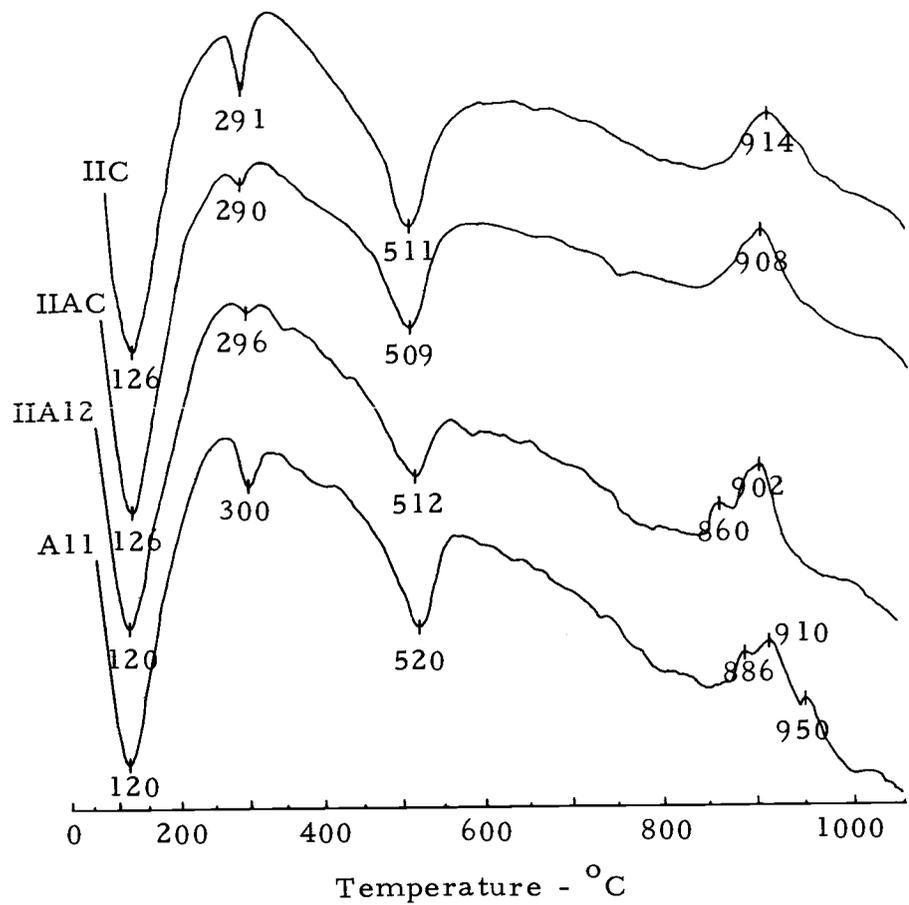
Figure 19. D.T.A. patterns of the Yaquina Head Ca-saturated clay
samples (Pretreatment I).
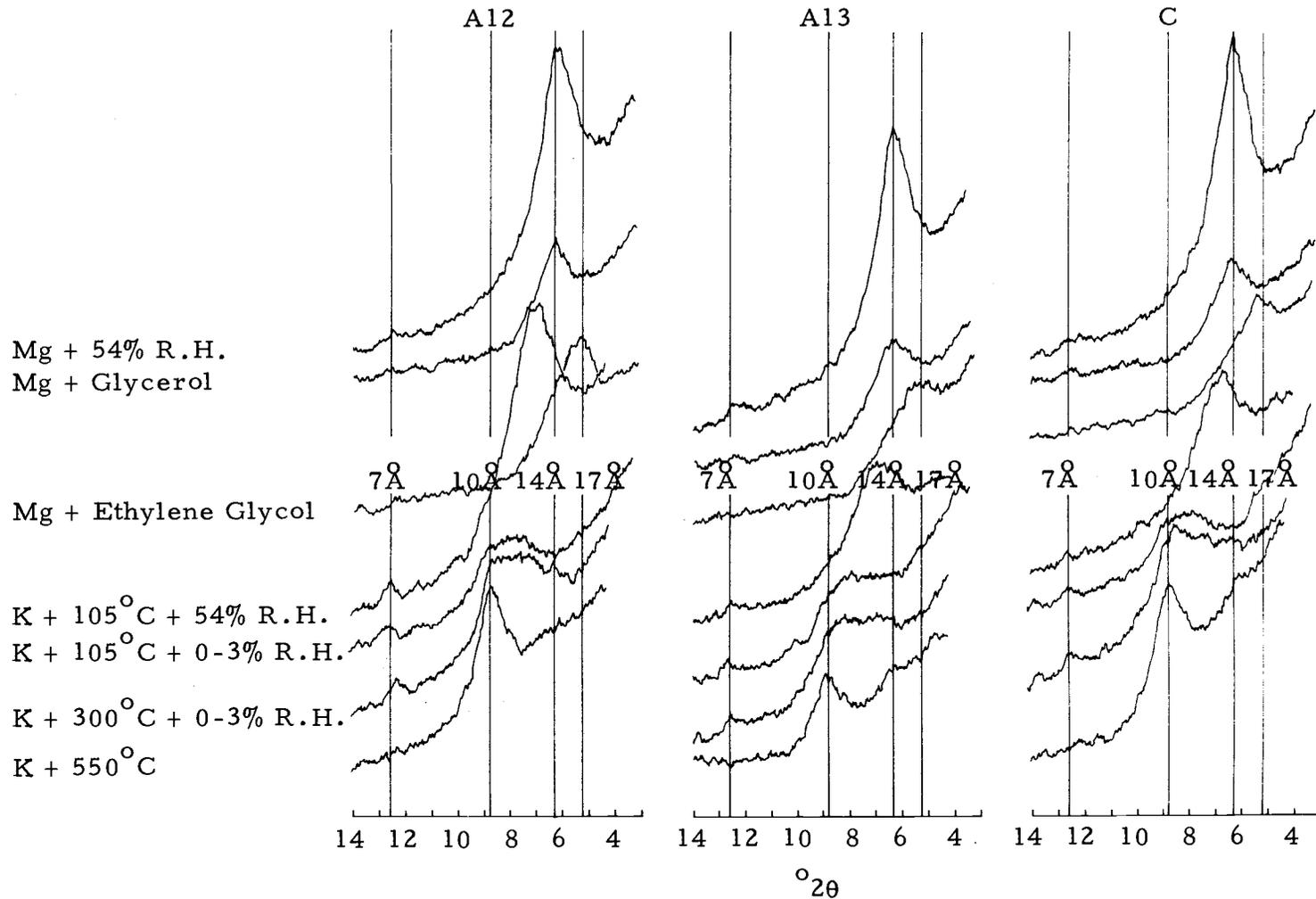
Figure 20. X-ray diffraction patterns of the Perpetua Head clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.
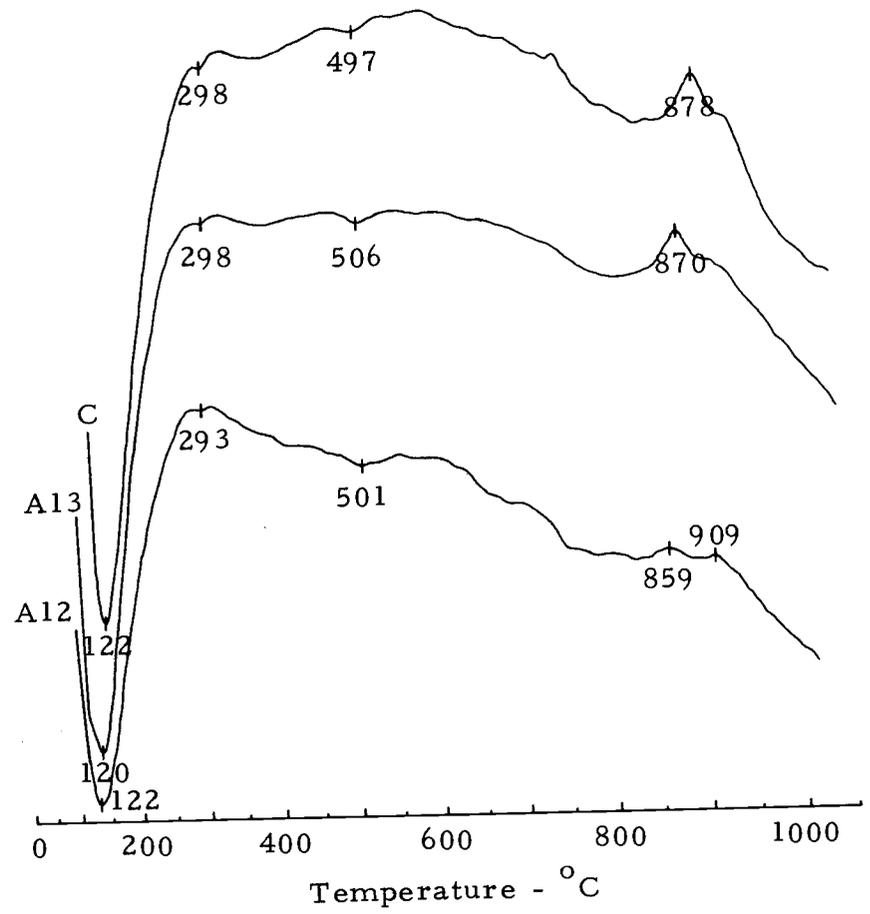
Figure 21. D.T.A. patterns of the Perpetua Head Ca-saturated clay
samples (Pretreatment I).
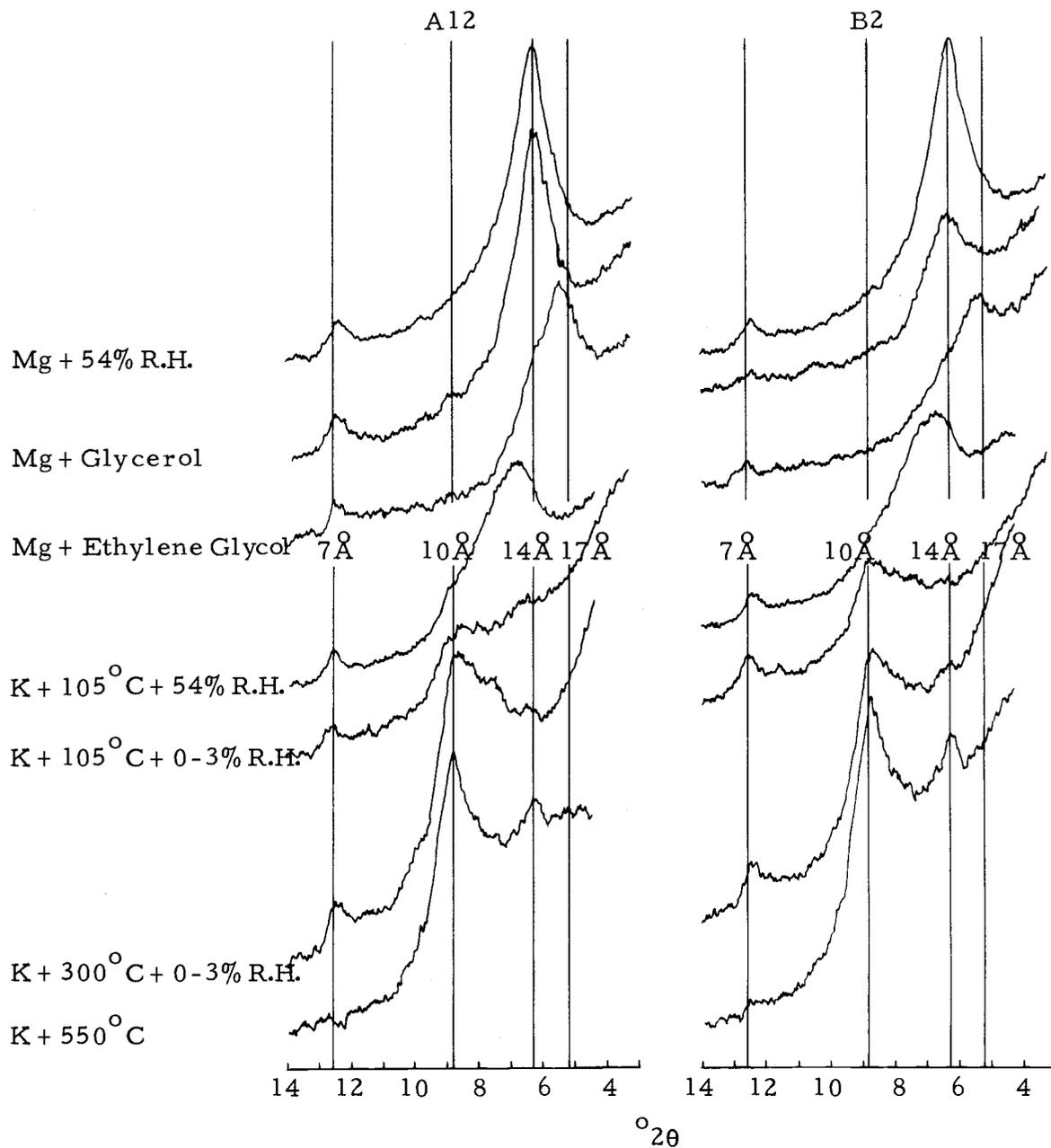
Figure 22. X-ray diffraction patterns of the Perpetua Beach clay samples
following the boiling 0.5 $\underline{N}$ NaOH treatment sequence for re-
moval of amorphous materials.
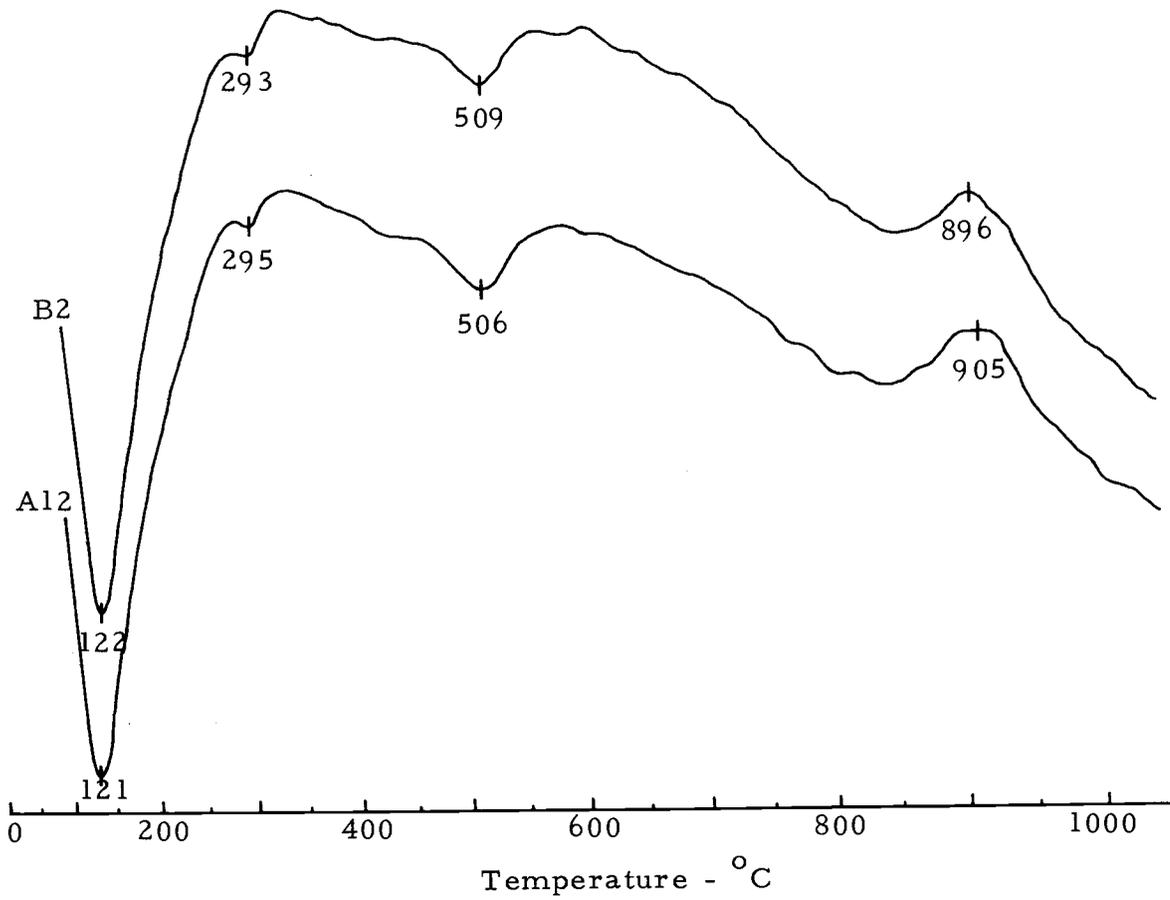
Figure 23. D.T.A. patterns of Perpetua Beach Ca-saturated clay samples (Pretreatment I).
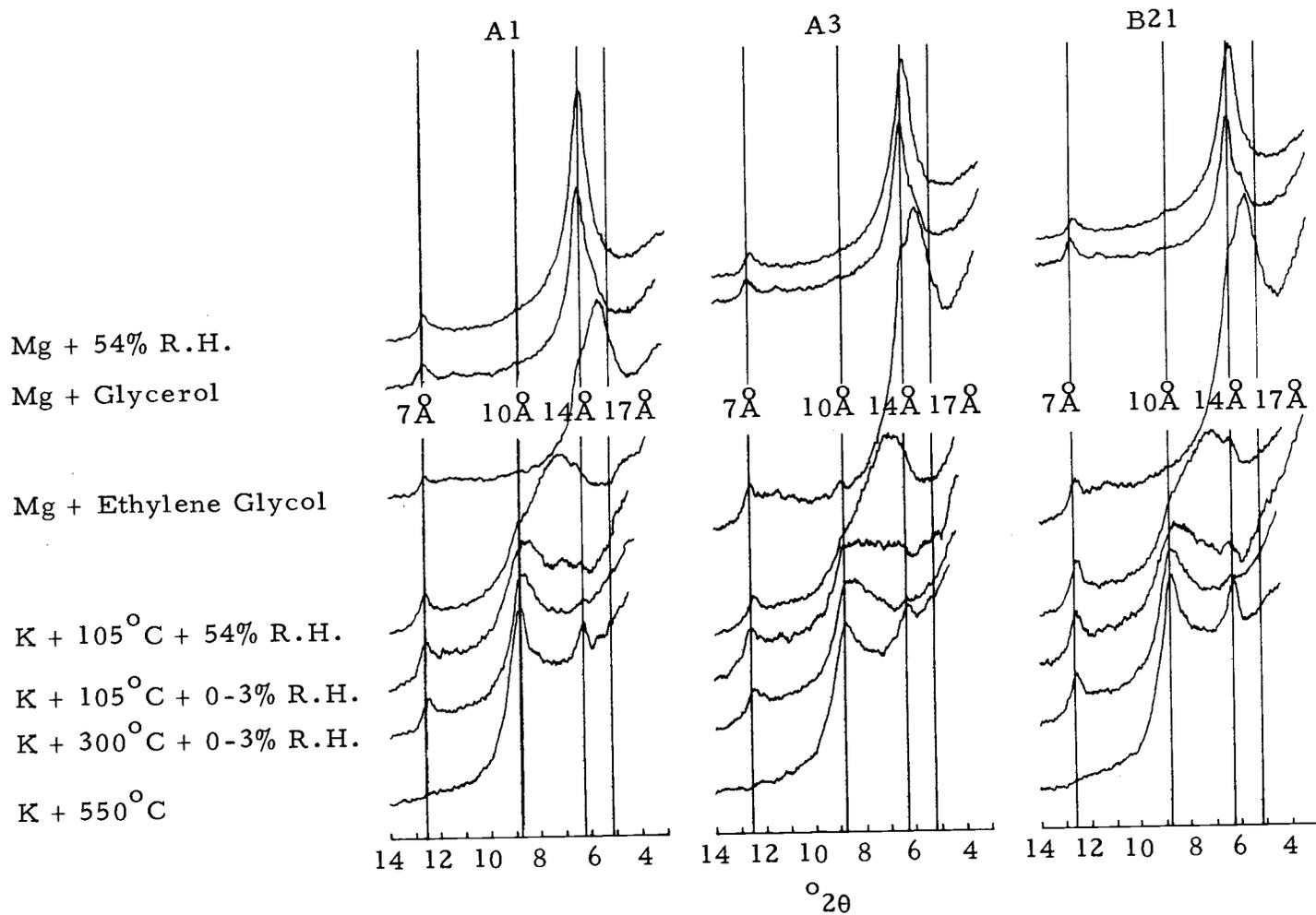
Figure 24. X-ray diffraction patterns of the Hembre clay samples following the boiling
0.5 $\underline{N}$ NaOH treatment sequence for removal of amorphous materials.
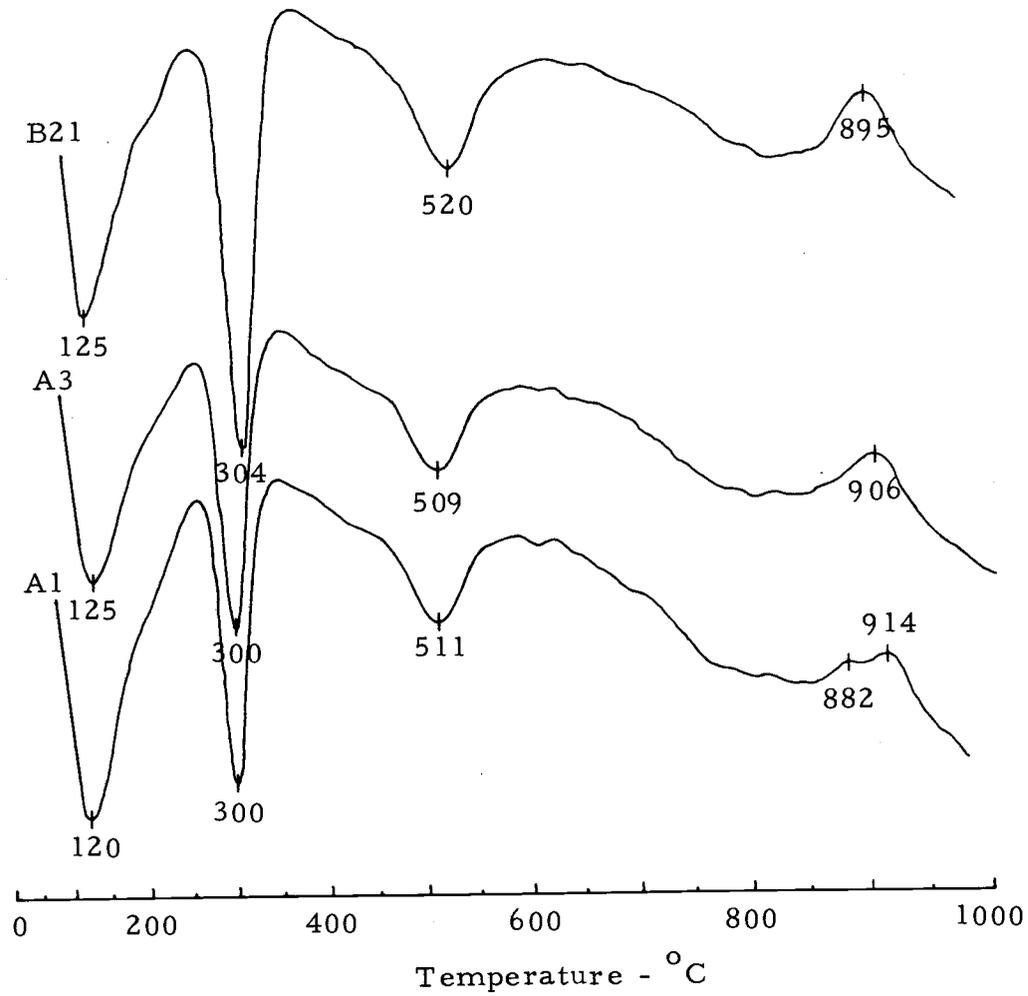
Figure 25. D.T.A. patterns of the Hembre Ca-saturated clay samples (Pretreatment I).

All

A12

Mg + 54% R.H.
Mg + Glycerol

Mg + Ethylene Glycol

7Å   10Å   14Å 17Å   7Å   10Å   14Å 17Å

K + 105°C + 54% R.H.
K + 105°C + 0-3% R.H.

K + 300°C + 0-3% R.H.

K + 550°C

14 12 10   8   6   4   14 12 10   8   6   4

°2θ
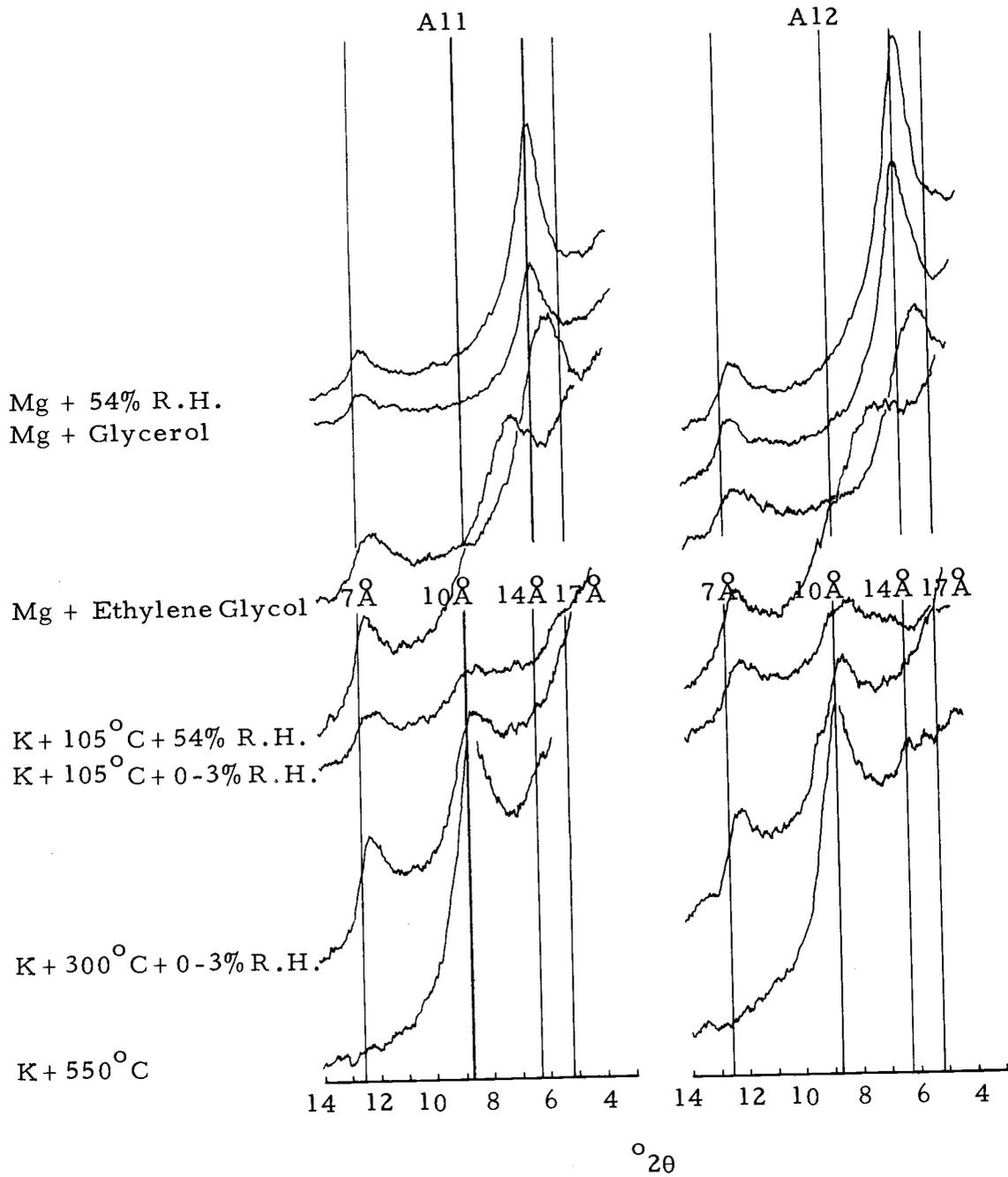
Figure 26. X-ray diffraction patterns of the Cascade Head clay samples
following the boiling 0.5 $\underline{N}$ NaOH treatment sequence for re-
moval of amorphous materials.
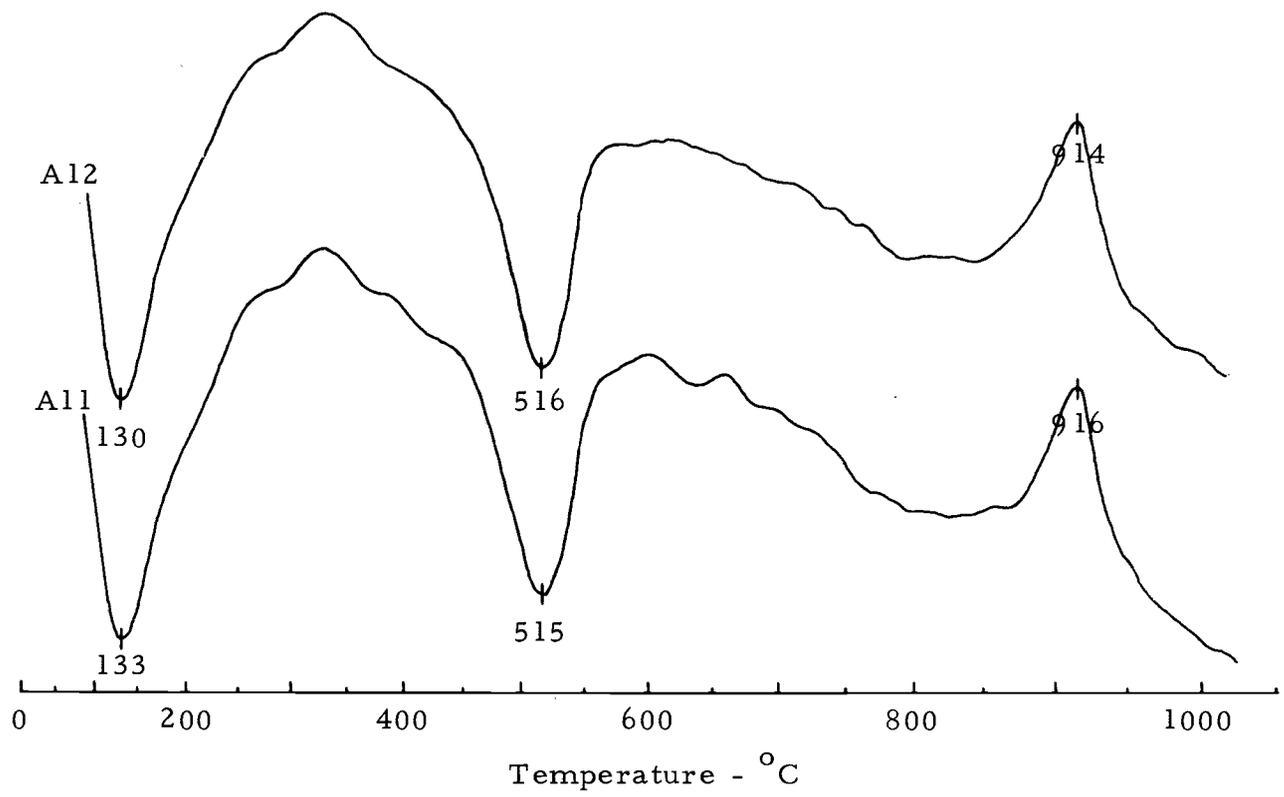
Figure 27. D.T.A. patterns of the Cascade Head Ca-saturated clay samples (Pretreatment I).
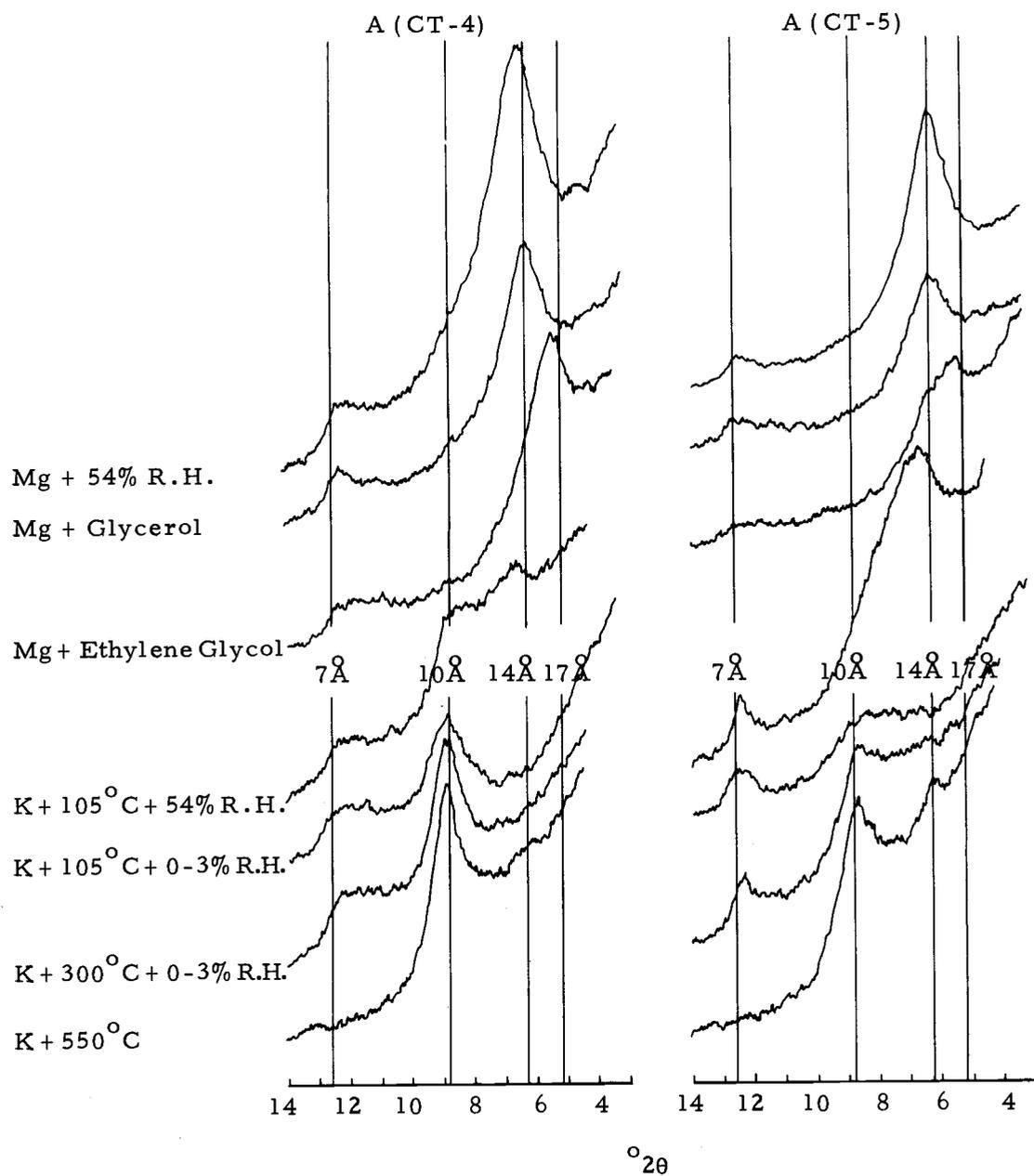
Figure 28. X-ray diffraction patterns of the Tillamook Head clay samples following the boiling 0.5 $\underline{N}$ NaOH treatment sequence for removal of amorphous materials.
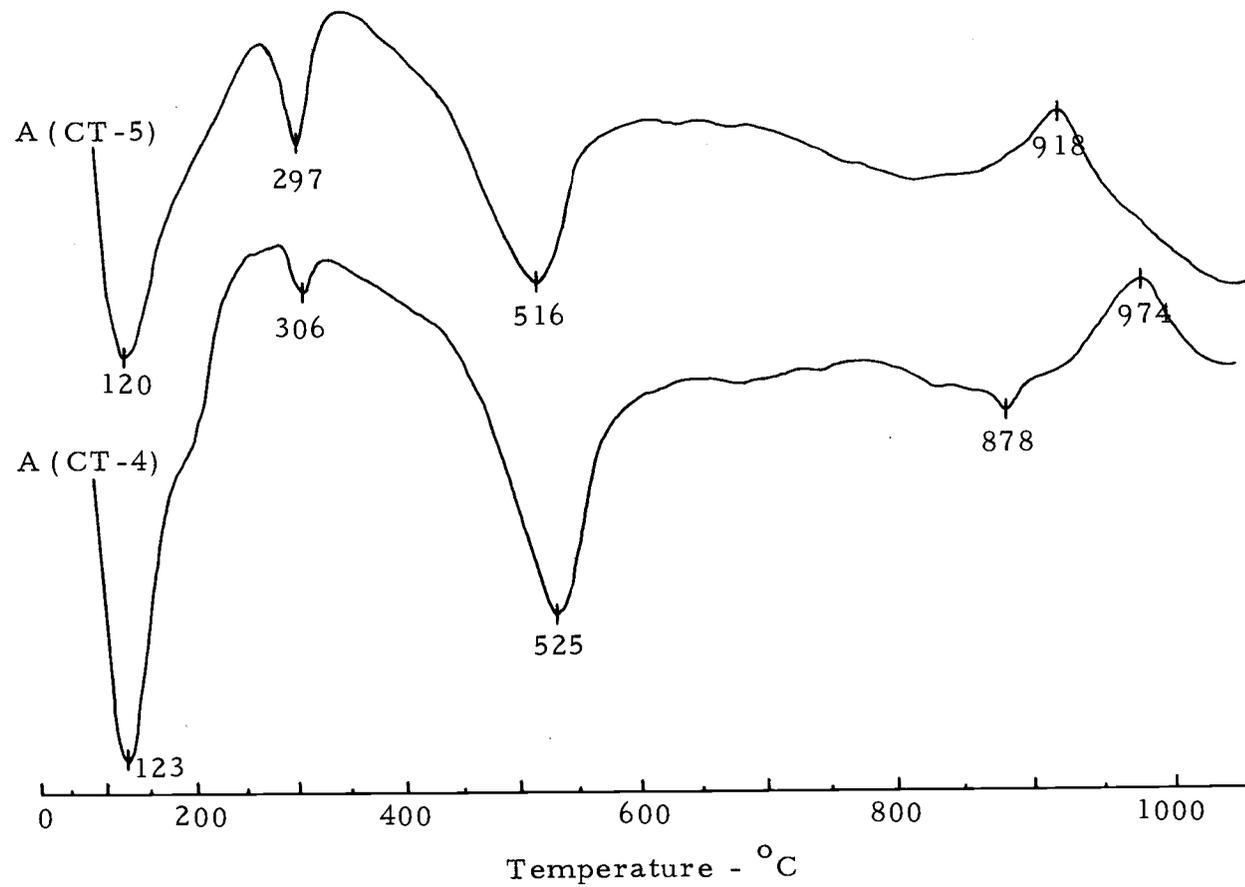
Figure 29. D.T.A. patterns of the Tillamook Head Ca-saturated clay samples
(Pretreatment I).
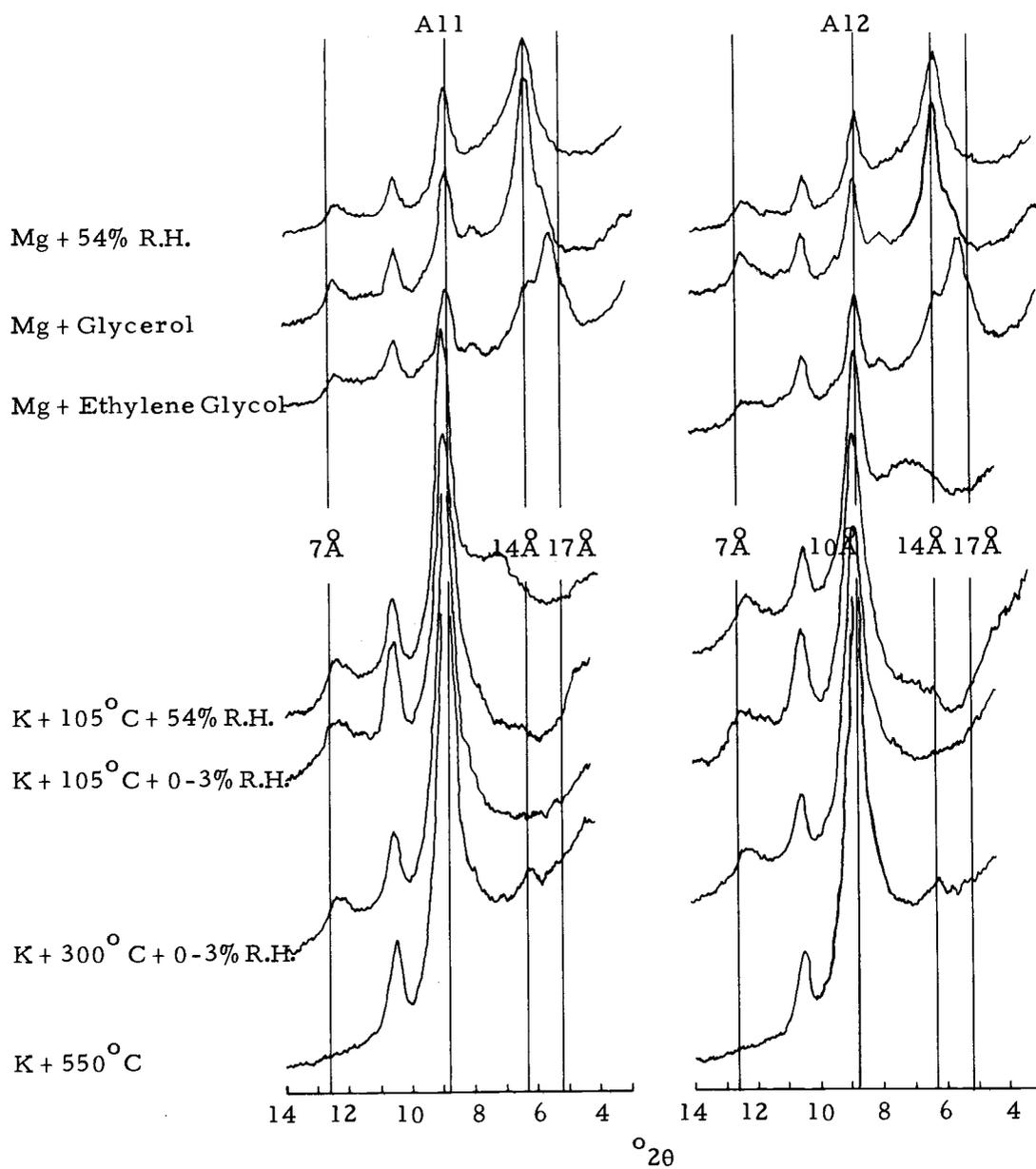
Figure 30. X-ray diffraction patterns of the Mulkey clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.
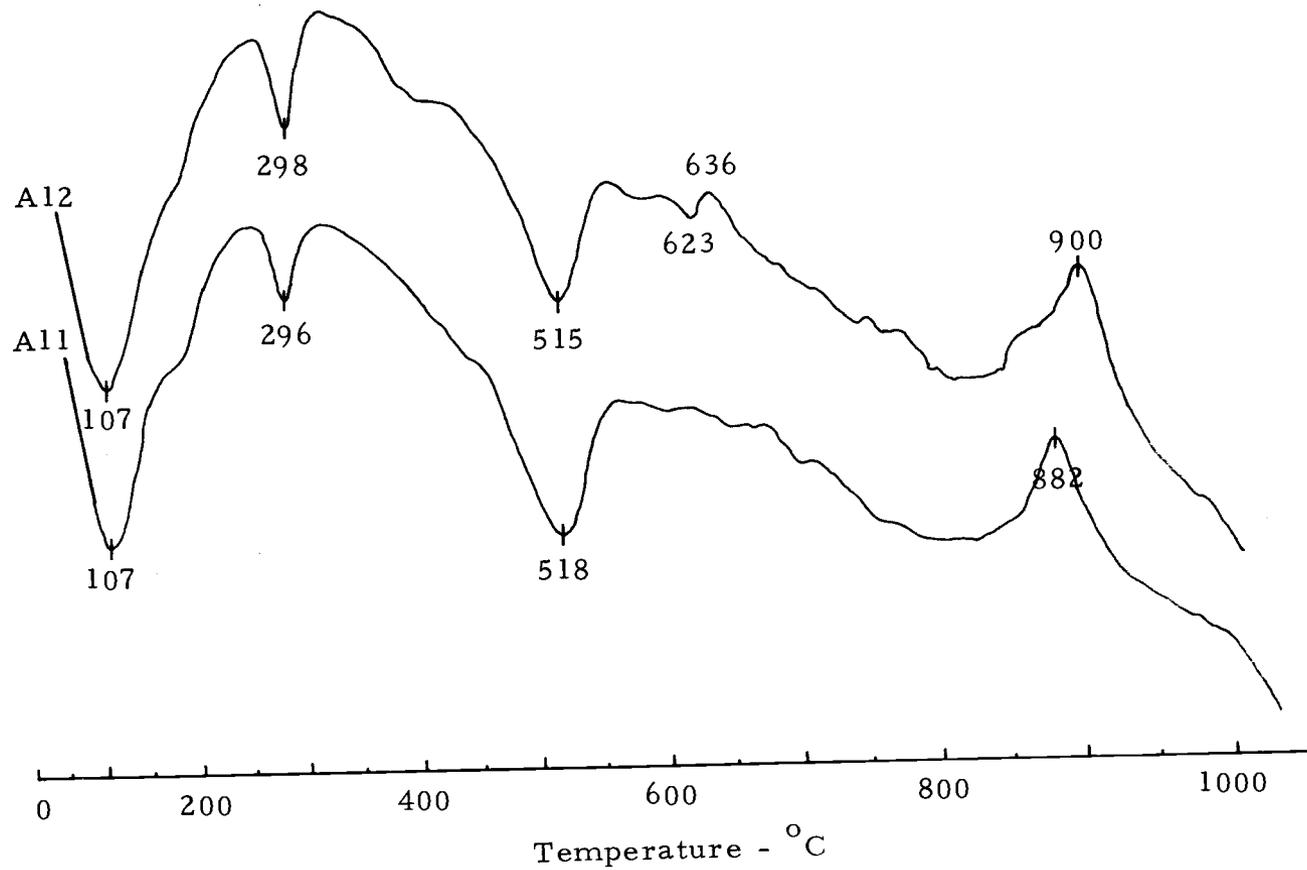
Figure 31. D.T.A. patterns of the Mulkey Ca-saturated clay samples (Pretreatment I).
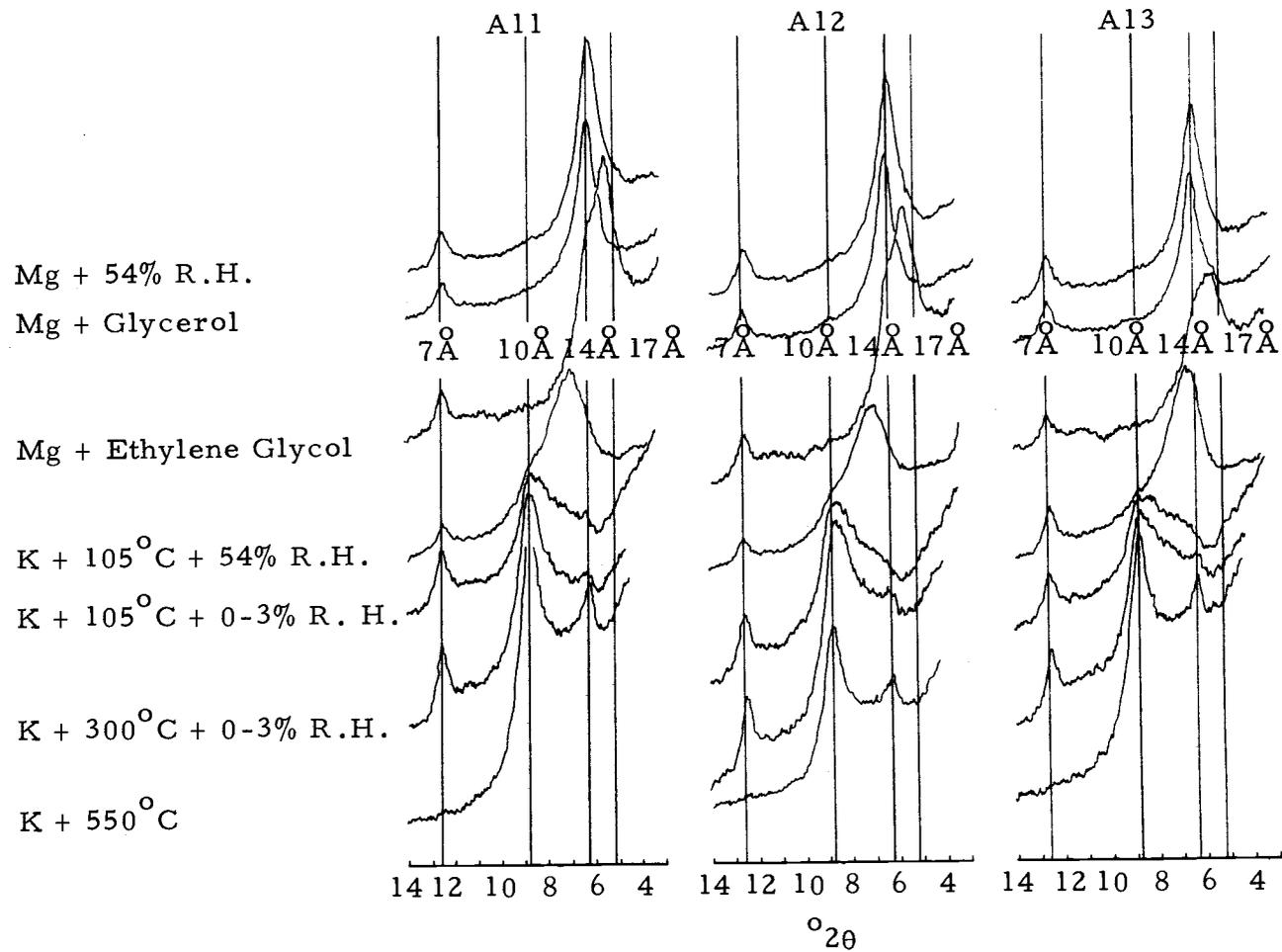
Figure 32. X-ray diffraction patterns of the Quillayute clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.
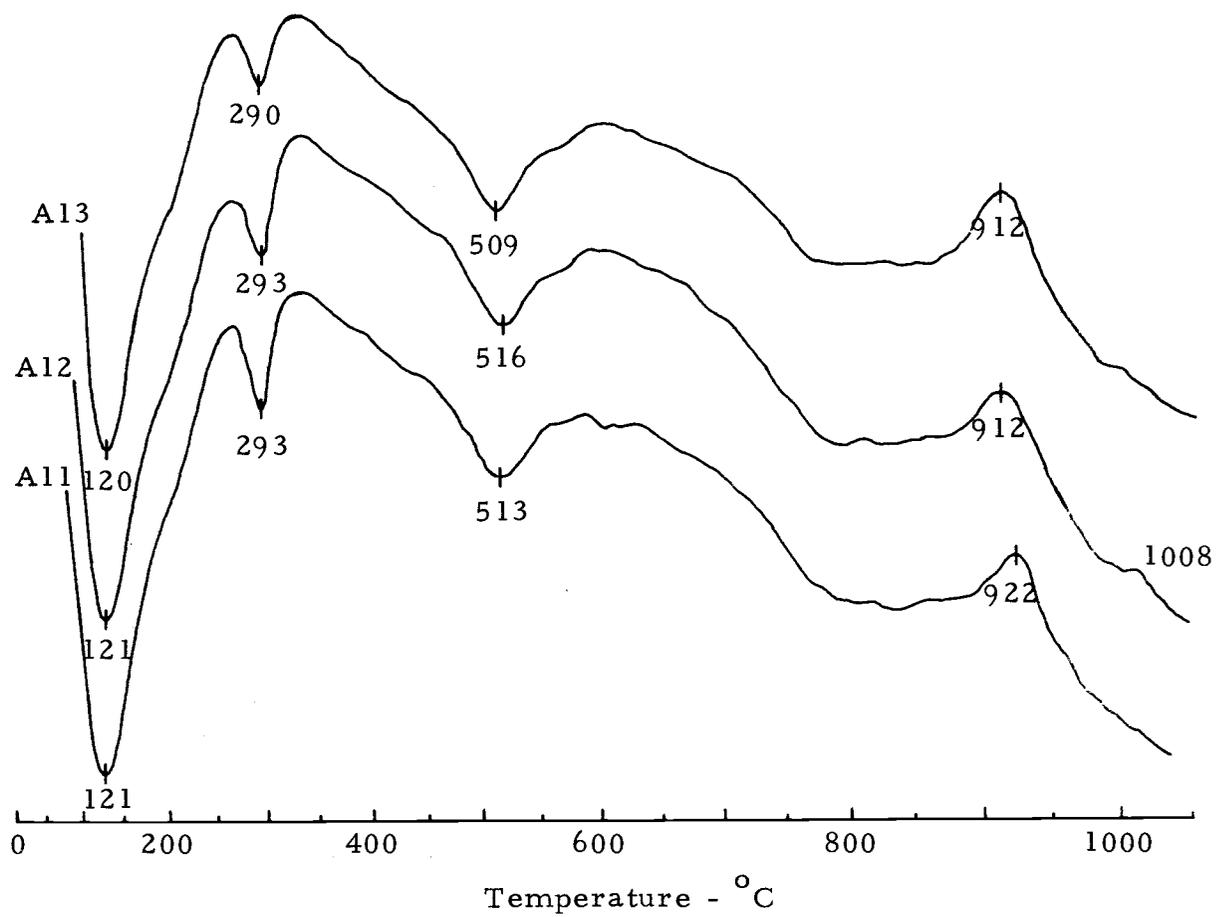
Figure 33. D.T.A. patterns of the Quillayute Ca-saturated clay samples (Pretreatment I).
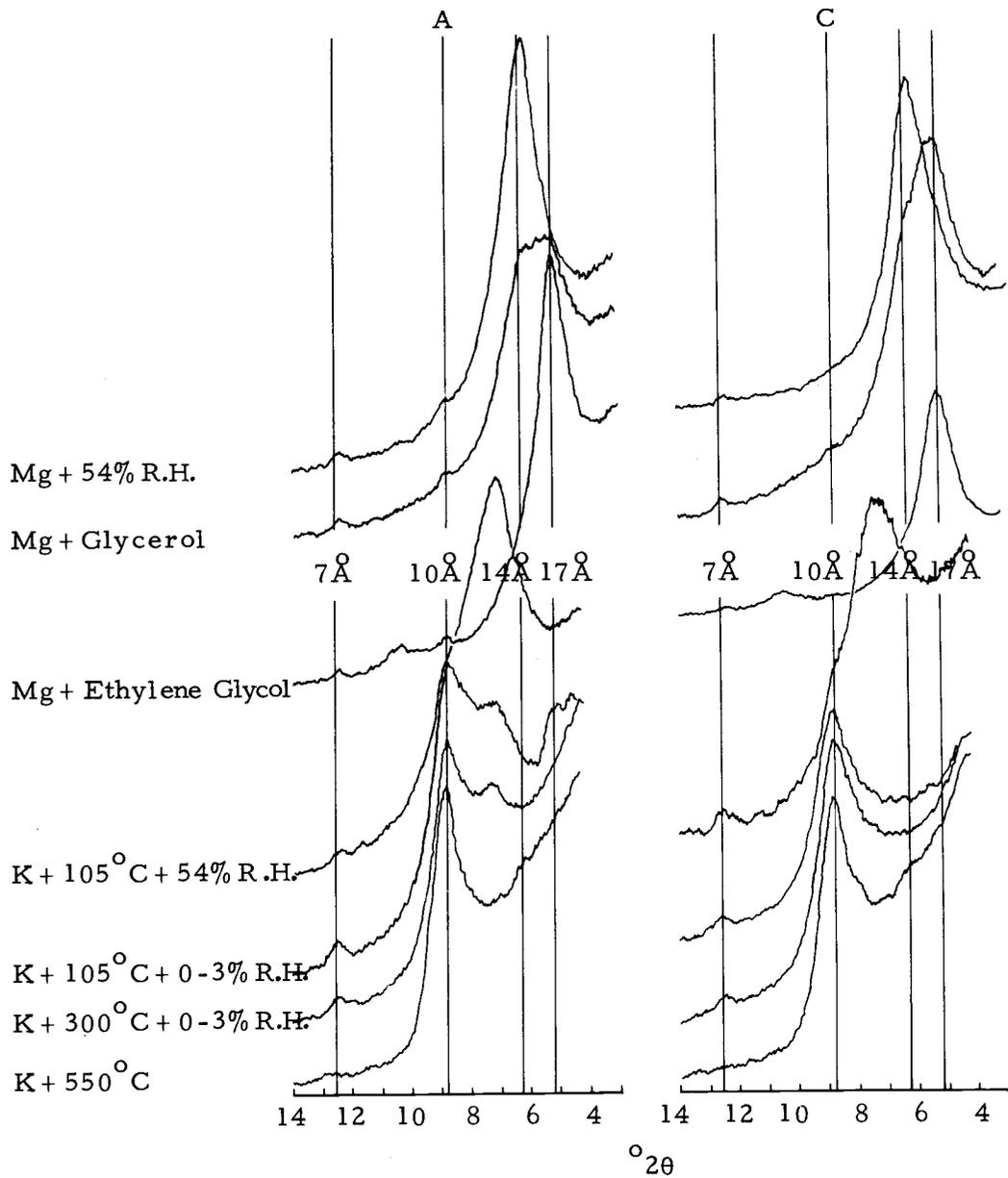
Figure 34. X-ray diffraction patterns of the Camas Prairie clay
samples following the boiling 0.5 N NaOH treatment
sequence for removal of amorphous materials.
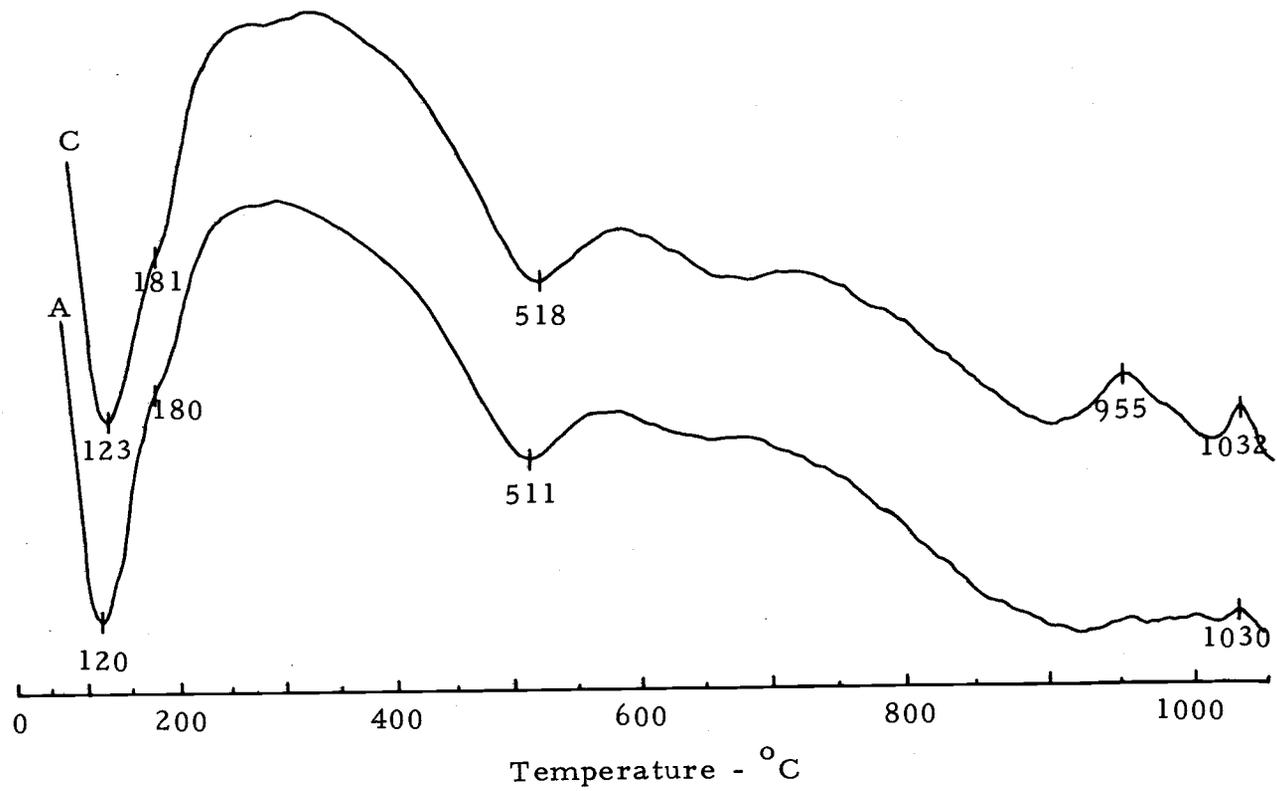
Figure 35. D.T.A. patterns of the Camas Prairie Ca-saturated clay samples
(Pretreatment I).

A11

A12

Mg + 54% R.H.
Mg + Glycerol

7Å   10Å   14Å 17Å   7Å   10Å   14Å 17Å

Mg + Ethylene Glycol

K + 105°C + 54% R.H.

K + 105°C + 0-3% R.H.

K + 300°C + 0-3% R.H.
K + 550°C

14   12   10   8   6   4   14   12   10   8   6   4

°2θ
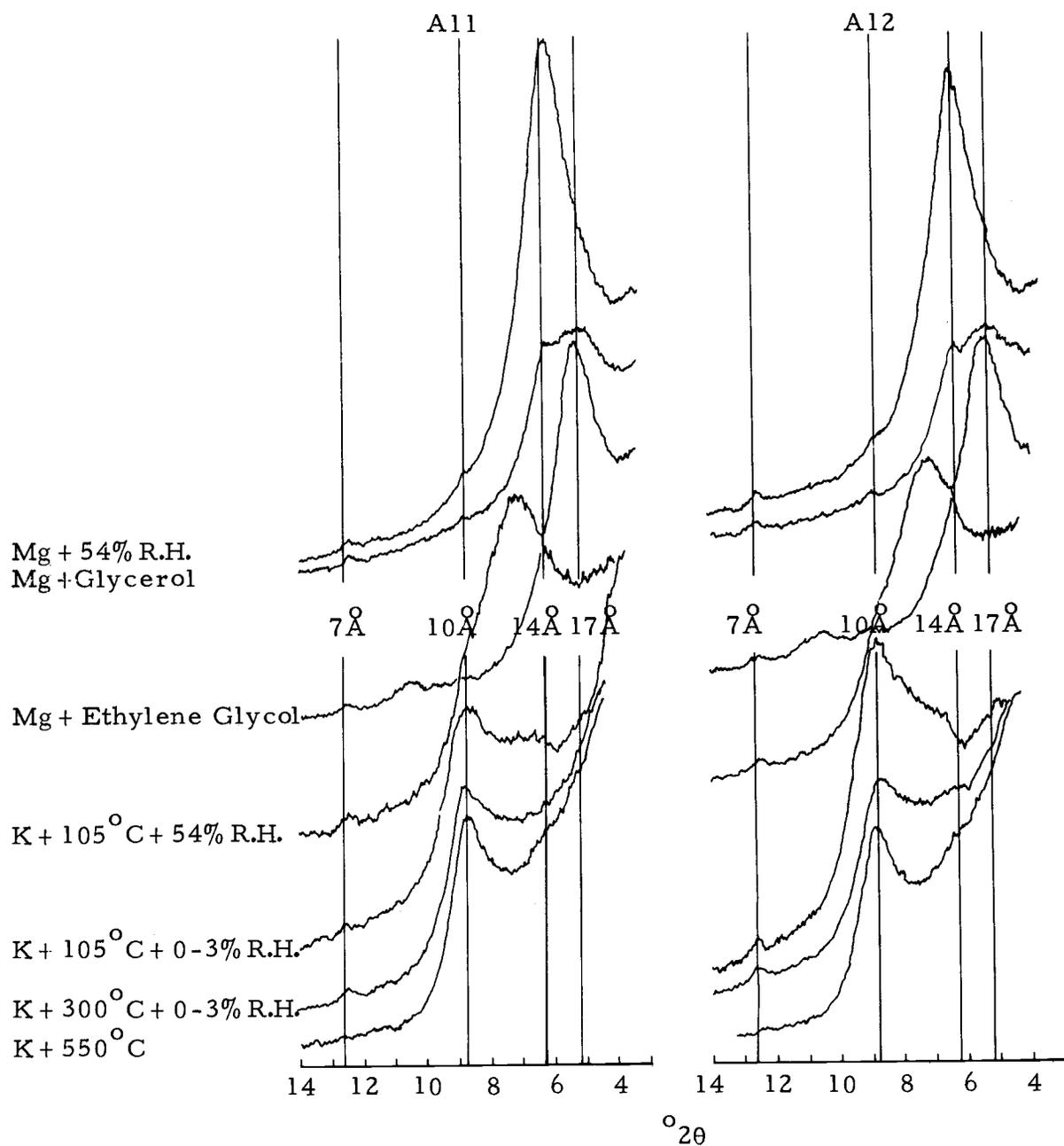
Figure 36. X-ray diffraction patterns of the Camas Ridge clay samples
following the boiling 0.5 N NaOH treatment sequence for re-
moval of amorphous materials.
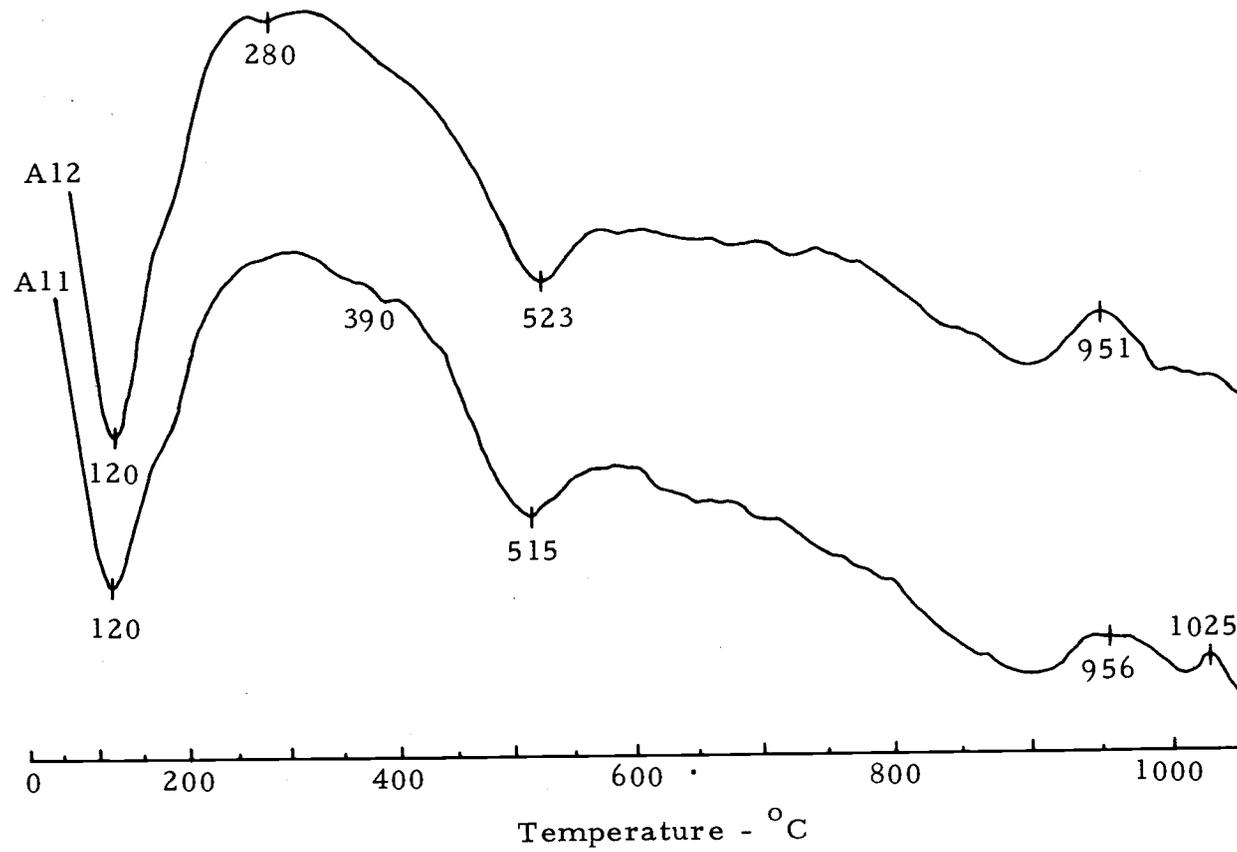
Figure 37. D.T.A. patterns of the Camas Ridge Ca-saturated clay samples (Pretreatment I).

Mg + 54% R.H.

Mg + Glycerol

Mg + Ethylene Glycol

K + 105°C + 54% R.H.

K + 105°C + 0-3% R.H.

K + 300°C + 0-3% R.H.

K + 550°C
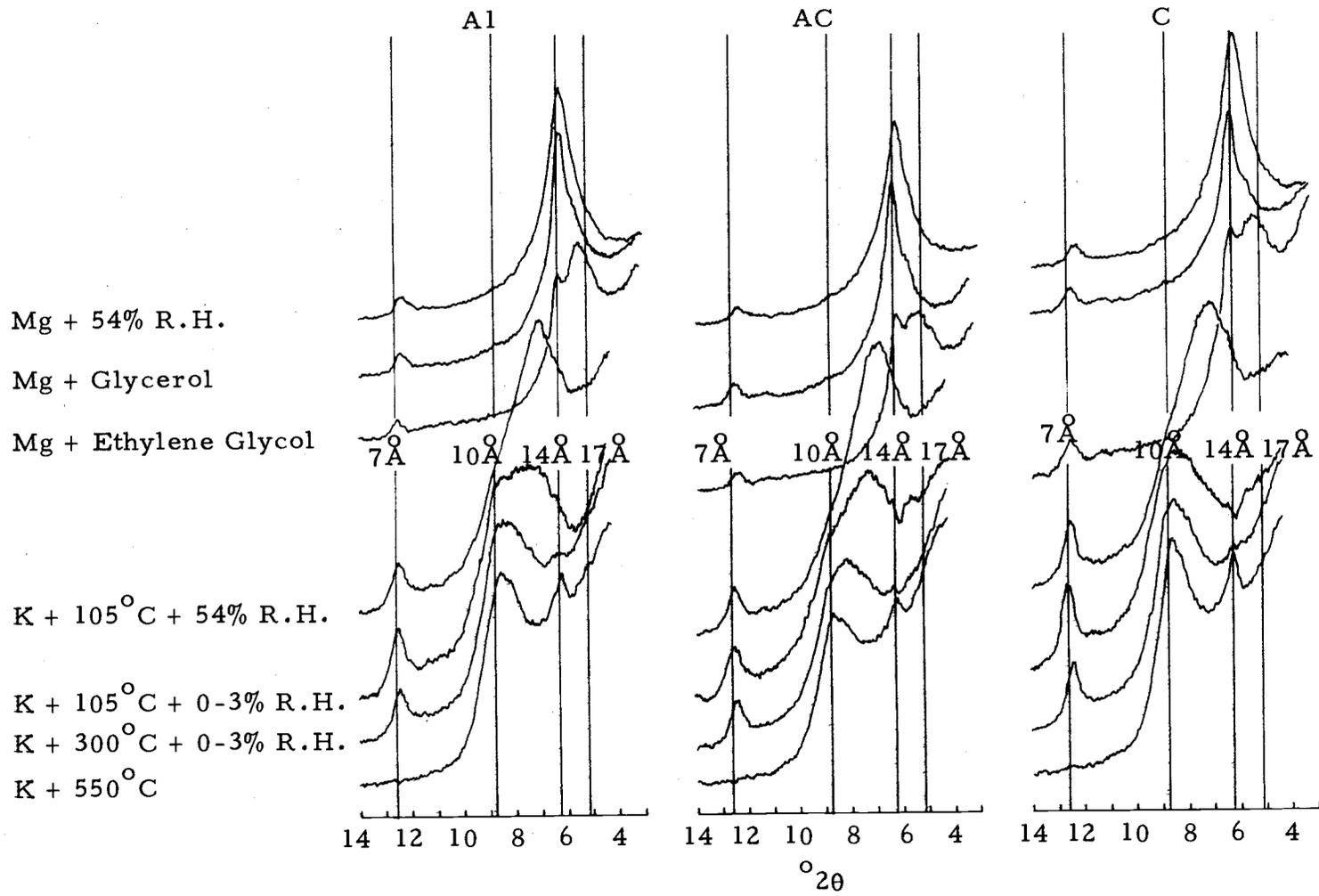
Figure 38. X-ray diffraction patterns of the Molock Beach clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.

114
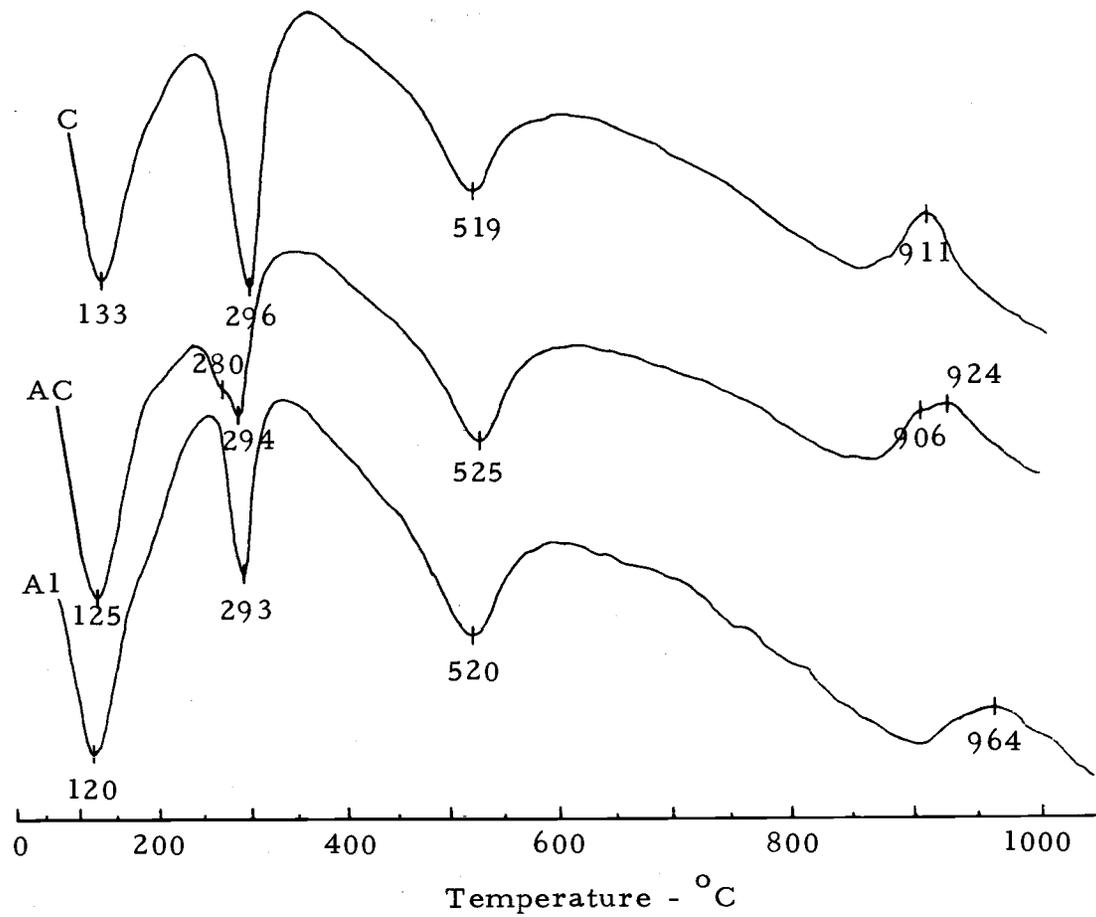
Figure 39. D.T.A. patterns of the Molock Beach Ca-saturated clay
samples (Pretreatment I).
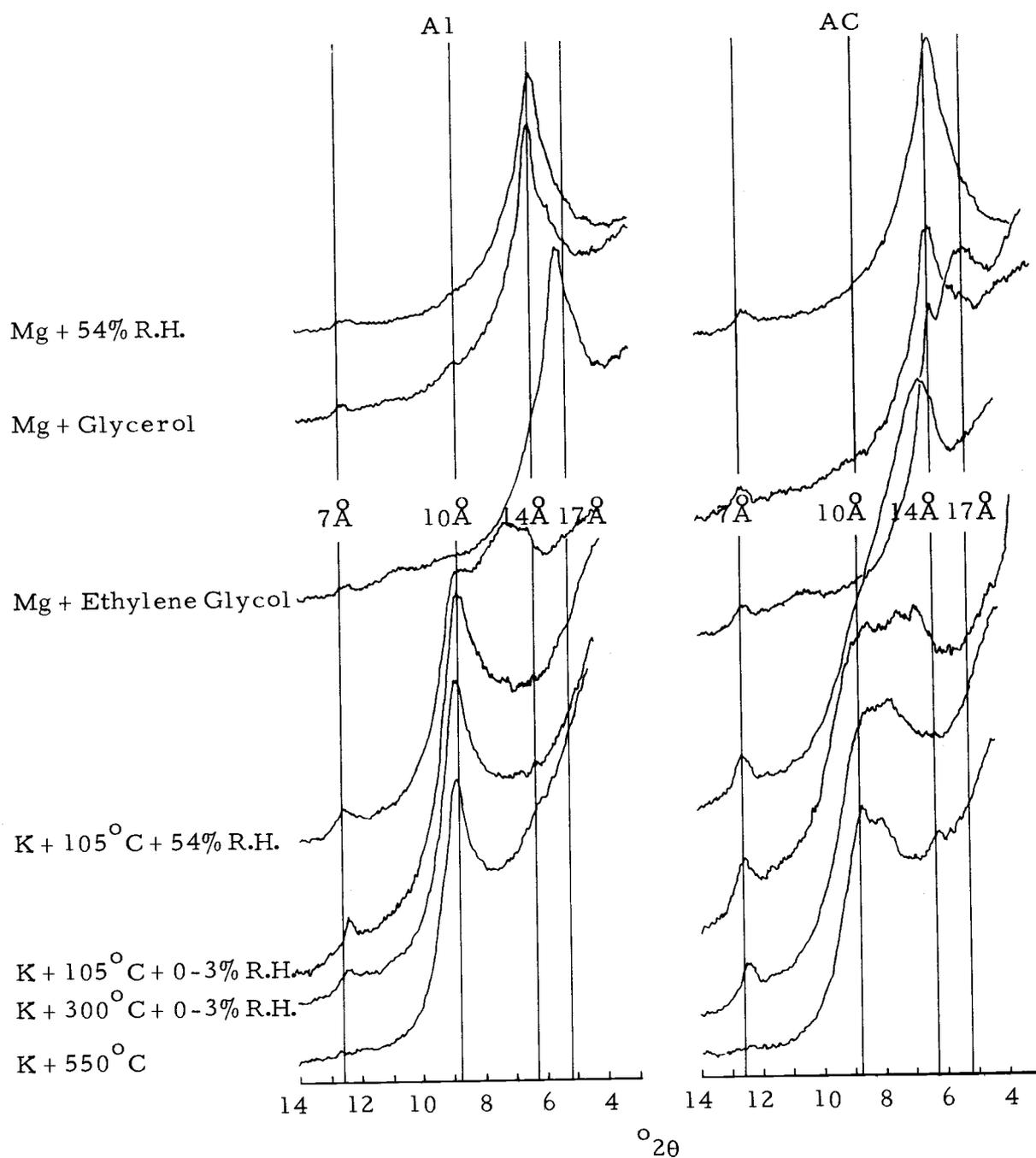
Figure 40. X-ray diffraction patterns of the Molock Creek clay samples following the boiling 0.5 N NaOH treatment sequence for removal of amorphous materials.
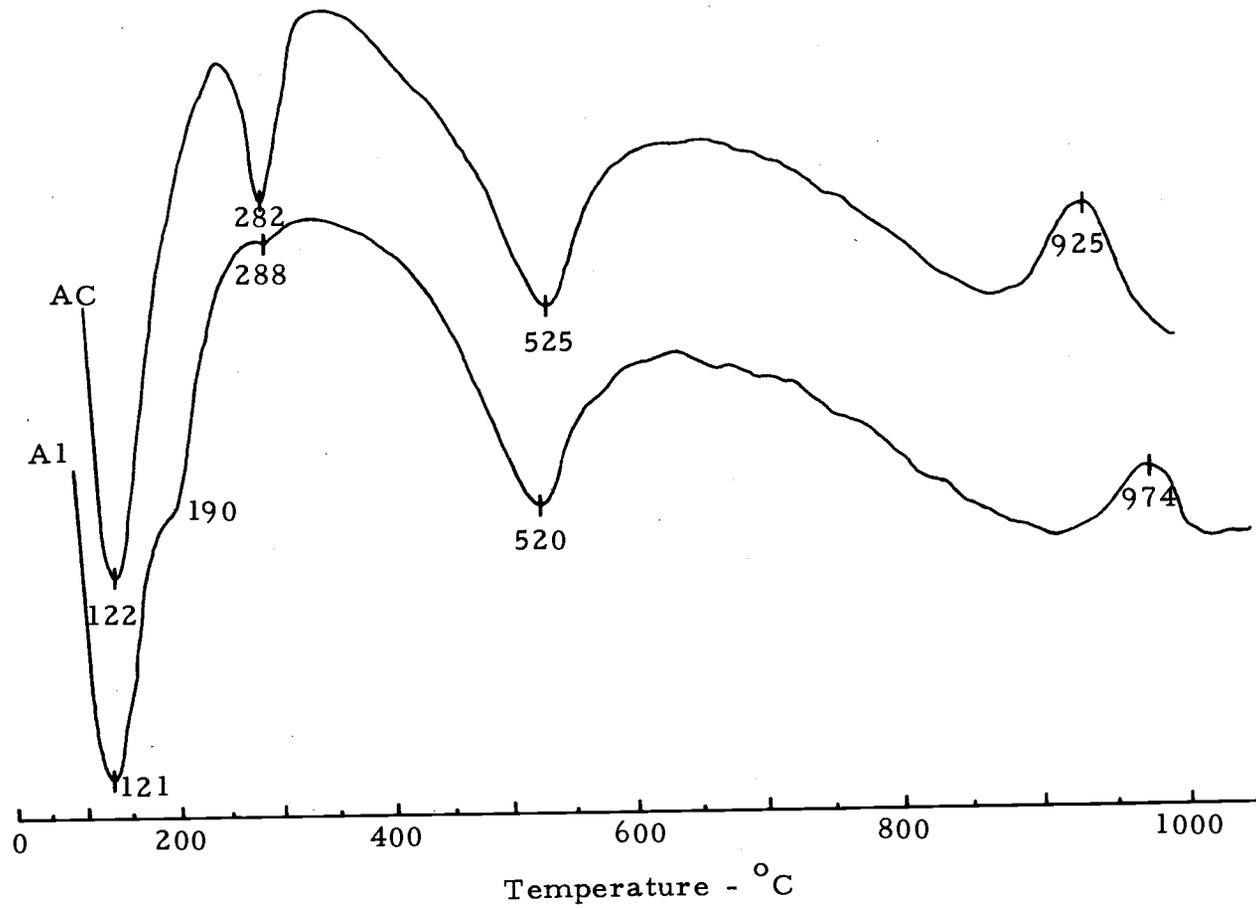
Figure 41. D.T.A. patterns of the Molock Creek Ca-saturated clay samples (Pretreatment I).

Chloritic intergrade. Chloritic material was found in varying amounts in every clay sample in the study. Only eight samples appear not to contain extensive hydroxy-interlayer material after one whole-soil iron-removal treatment. These samples were the Tilla-mook Head (CT-4) A horizon, the Mulkey soil, the Camas Prairie soil, the Camas Ridge soil and the Molock Creek A1 horizon. The collapse of the Pretreatment I (1 whole-soil iron-removal pretreat-ment) K-saturated samples and expansion of Mg-saturated ethylene glycol solvated samples from these horizons were not greatly differ-ent from those shown in the diffractograms obtained after the boiling NaOH treatment (Figures 28, 30, 34, 36, and 40). Chloritic inter-grade clays, approaching a chlorite end-member, occurred in the majority of the samples. The resistance to collapse of these K-saturated samples heated at 105 and 300° C was notable even after the boiling NaOH treatment (Figures 16, 18, 20, 22, 24, 26, 28, 32, 36, 38, 40).

Except for the Camas Prairie soil, the clay samples with mini-mal cleaning (Pretreatment I) exhibited a greater resistance to collapse to 10 $\overset{o}{A}$ as the sample depth increased for a particular soil. After the boiling NaOH treatment, C horizon samples exhibited a greater tendency to collapse with heat treatment than the correspond-ing A horizon samples. The apparently less stable hydroxy-inter-layer material found in the C horizon samples of this study agrees

with the findings of Sawhney (1958, 1960) who observed that the

hydroxy-interlayer material found in the subsoil was less stable than

that found near the soil surface. However, the results of this study

do not completely agree with Jeffries, et al. (1953), Tamura (1956),

Pawluk (1963) and Jones and Beavers (1964) who reported that

chloritization increases toward the surface of soil profiles. The Al

or All horizon of most of the soils in the study contained less hydroxy-

interlayer material than the sub-horizons. A notable example of this

is found in the Molock Creek soil (Figure 40). The accumulation and

loss of hydroxy-interlayer material may be cyclic, especially in the

forested Oregon soils. Humic compounds may occupy a part of clay

interlayer spacing before or after hydroxy-interlayer formation. The

absorption of fulvic acid in the interlayer spaces of Na-montmorilli-

nite at less than pH 5 was demonstrated by Schnitzer (1969). Humic

compounds probably reduce the amount hydroxy-Al or hydroxy-Fe

interlayers by formation of stable humus-Al or humus-Fe.

Chloritic intergrade clays appear to be common in western

Oregon soils (Jenne, 1961; Harward and Theisen, 1962; Singleton,

1966; and Chichester, 1967). Carstea (1965) and Singleton (1966)

extensively reviewed the literature concerning the occurrence and

theories of chloritic intergrade formation. Therefore, no further

review will be made here.

Kaolin group and chlorite minerals. The detection of kaolinite

from x-ray diffraction data is usually simple because of its prominent

basal (001) first-order reflection at about 7.15 Å and a second-order

reflection of approximate equal intensity at 3.57 Å. However, the

presence of chlorite in the clay sample may bring about confounding

in establishing the presence of kaolinite. Chlorites rich in Fe fre-

quently give weak first- and third-order reflections and strong

second- and fourth-order reflections which closely coincide with

those of kaolinite. In this case, the differentiation of the kaolinite

from chlorite is particularly difficult (Grim, 1968, p. 130).

Absolute proof of the presence or absence of kaolinite could

not be established in any of the clay samples from either the D.T.A.

thermograms or x-ray diffractograms, in the latter case, because of

the presence of chlorite in most of the samples. However, the

presence of a kaolin mineral, believed to be a low-hydration type

halloysite, is strongly indicated by the x-ray and D.T.A. patterns of

several samples (Cascade Head, Figures 26, 27; Tillamook Head,

Figures 28, 29); and Mulkey, Figures 30, 31). These x-ray diffrac-

tion peaks indicating kaolin occur mainly at 7.2 to 7.4 Å. The assym-

metric dehydroxylation peaks in the D.T.A. thermograms are sug-

gestive of halloysite. The peak temperatures (515-520° C) are

slightly lower than is expected for halloysite (Table 8). The lower

peak temperatures might be due to a poorly crystalline halloysite mineral.

Less baseline drift can be noted for the Cascade Head and Tillamook Head samples than for others which contain larger amounts of expanding-lattice clays.

The Tillamook Head, CT-4, x-ray diffractograms show an unusually broad shoulder extending between 7.2 to 8.4 Å which persists after heating to 300° C (Figure 28). This was also reproduced in diffractograms of samples which were given several additional iron-removal treatments. Alternately possible explanations for this phenomenon are: (1) random interstratification of 7 and 10Å minerals or (2) very poorly crystalline kaolin mineral (axis disorder). The 974° exotherm found in the D. T. A. thermogram (Figure 29) is much higher than the approximate 900° C peak temperature usually found for soil kaolins (Barshad, 1965, p. 719). Random interstratification appears to be the most plausible explanation for the broad x-ray diffraction shoulder. However, it is felt that neither of the explanations offered is adequate.

Quite symmetric dehydroxylation peaks occurring in samples of other soils might be taken as an indication of the presence of kaolinite. However, symmetric endothermic dehydroxylation peaks also occur for beidellite and nontronite (Ross and Mortland, 1965; Figure 15).

The presence of chlorite in most of the soils in the study was indicated by x-ray peaks at 3.54 and 4.74 Å and at about 7.1 and 14.2 Å. The first-order (14 Å) and third-order (4.7 Å) were weaker

than the second-order (7 Å) and fourth-order (3.5 Å) peaks. The

first-order 14 Å peak generally was not discernable until the K-satu-

rated samples were heated to at least 300° C. Heating the K-satu-

rated samples to 500 or 550° C resulted in reinforcement of the 14 Å

peak. Chlorophaeite may be the primary source of chlorite in soil

clays formed from the basaltic rocks. Chlorophaeite was very abun-

dant in the Yaquina Head and Price Peak rock thin sections.

The boiling NaOH treatment resulted in some broadening and

almost elimination of the chlorite reflections in some cases. For

example, the Camas Prairie (Figure 34) and Camas Ridge (Figure 36)

K-saturated samples receiving several iron-removal treatments

showed small 14 Å peaks after heating to 500° C (this data not shown)

whereas, 14 Å peaks in samples heated to 550° C after the boiling

NaOH treatment are scarcely or not at all discernable.

Smectite, vermiculite and mica. The incomplete removal of

interlayer material from the samples complicated the interpretation

of x-ray diffraction patterns of samples with treatments designed to

differentiate types of smectites and differentiate vermiculite from

smectite. Because hydroxy-interlayer material forms in both

smectite and vermiculite (Carstea, 1967; Singleton, 1966), the likeli-

hood of determining whether the chloritic intergrade matrix is a

particular smectite, a vermiculite or both is considerably reduced

unless fairly complete hydroxy-interlayer removal is achieved.

interlayer material. In general, as the amount of interlayer material

in the sample increased, the less was the tendency for the sample to

The possible presence of vermiculite in all the samples is indicated by small to large 10 Å peaks, breaks or shoulders in the x-ray patterns of K-saturated samples heated to 105° C and equilibrated at 54% R.H. Expansion of the 14 Å peak to 17 Å upon ethylene glycol solvation is a negative indication of vermiculite in the Tillamook Head (CT-4), Camas Prairie, Camas Ridge, and Molock Creek Al samples. In other clay samples incomplete removal of hydroxy-interlayer material, which resulted in resistance to expansion with ethylene glycol, reduced the usefulness of this test for vermiculite identification. Vermiculite appears to be a major clay component in only one soil, the Mulkey (Figure 30).

The presence of a smectite component in all the samples is shown by reexpansion of K-saturated samples equilibrated at 54% R.H. to 12 Å or more. Unremoved hydroxy-interlayer material in the samples tended to shift the x-ray peak maxima from about 12.5 Å to 13 Å or over. The difference in expansion of Mg-saturated samples obtained with ethylene glycol and glycerol vapors is a basis for differentiating beidellite and nontronite, which have substitution Al for Si in the tetrahedral layer, from montmorillinite which has little or no tetrahedral substitution. The glycerol solvation treatment of the clays in the study was extremely sensitive to the presence of interlayer material. In general, as the amount of interlayer material in the sample increased, the less was the tendency for the sample to

expand. The greatest amount of expansion with glycerol of any sample in the study was with the Camas Prairie, C horizon (Figure 34). Complete expansion of the whole sample was not obtained even in this case. The Molock Creek Al horizon sample shows a greater resistance to expansion with glycerol than the Camas Prairie sample. The incomplete expansion could be due to the presence of beidellite or nontronite.

The differential thermograms of the samples give some indication that clays approaching beidellite or nontronite might be present. The D.T.A. patterns of the Camas Prairie soil clays (Figure 35) shows dehydroxylation endotherms at 511 and 518° C which are much lower than the 850-925° C endotherms usually found in montmorillinite with a high degree of Mg substitution in the octahedral layer (Jackson, 1956, p. 269). The approximate 500° C endotherms are in the range of a poorly crystalline halloysite or kaolinite, also. However, the A horizon sample does not exhibit a recrystallization exotherm indicative of a kaolin mineral. The C horizon sample exhibits two exotherms, at 955 and 1032° C. The 955° C exotherm is higher than that usually found for soil kaolins (about 900° C; Barshad, 1965, p. 719). The double exotherm may be indicative of a mixture of high and low charge density smectities. The differential thermograms of the Camas Ridge samples (Figure 37) are similar to the Camas Prairie except that the Al2 horizon sample does not show the

exotherm at approximately 1030° C. The Molock Creek Al D. T. A.

pattern shows a dehydroxylation endotherm at 520° C and an exotherm

at about 975° C. This sample may be a relatively pure beidellite.

Mica was a substantial constituent in the clay of only one soil,

the Mulkey (Figure 30). Very small 10 Å peaks in the diffractograms

of Mg-saturated slides, x-rayed at lower rate settings than those

used for the figures which are shown, indicate that trace amounts of

mice are probably present in some clay samples of all other soils

except the Cascade Head (this data not shown).

Gibbsite, quartz, feldspar and amphibole. All the soil clays

in the study, except three (Cascade Head, Camas Prairie and Camas

Ridge), contained gibbsite. The occurrence of soil gibbsite is illus-

trated most graphically in the D. T. A. patterns. In general, the

gibbsite D. T. A. endothermic peak temperature maxima occurred at

about 300° C. This is somewhat lower than the 328° C temperature

given by Barshad (1965, p. 720) for well-crystallized samples. How-

ever, highly gibbsitic nodules found at about the 3-m depth in the

Molock Beach subsoil showed a peak maxima of 321° C.

Using D. T. A. peak height as an indication of relative amounts

present, the gibbsite increased with depth in all soils, except the

Yaquina Head (Figure 19). In this soil the All horizon, consisting of

a recent eolian deposit, contained more gibbsite than the IIA12 hor-

izon. The amount of gibbsite in the various samples ranged from

minor amounts (Figures 21, 23, 27, 35, and 37) to substantial

amounts. The largest amount of gibbsite was found in the Hembre

B21 horizon (Figure 25). Using D. T. A. peak heights and the boiling

0.5 $\underline{N}$ NaOH weight loss values for the highly gibbsitic nodules from

the Molock Beach subsoil as a standard to obtain a rough gibbsite

content estimate, the gibbsite content of the Hembre B21 sample

is in the order of 18%.

Small quartz peaks (3.34 Å) were found in the x-ray patterns of

all the clay samples. In general, the quartz peak tended to be slightly

greater in the samples which were alluvial and sedimentary in origin.

Small, but definite, feldspar peaks were found in clay samples

of the Yaquina Head, Perpetua Beach and Mulkey soils.

The Mulkey soil (Figure 30) is somewhat unusual in that the

clay fraction contains an amphibole which, most likely, is horn-

blende. This peak occurs at about 8.4 Å in the x-ray diffractograms.

Boiling 0.5 $\underline{N}$ NaOH Soluble Constituents

Special emphasis is placed on the amorphous alumino-silicate

(usually referred to as allophane) content of a soil as a criteria for

classifying a soil as an "Andept" in the U.S.D.A. Comprehensive

Soil Classification System (Soil Survey Staff, 1960). The boiling 0.5

$\underline{N}$ NaOH treatment and analysis was carried out in an attempt to obtain

a quantitative measure of this in the clay samples.

The clay weight losses resulting from the boiling 0.5 $\underline{N}$ NaOH treatment sequence on samples given cleaning Pretreatments I and II are shown in Table 9. The molar Si/Al ratios from the sequence extract analyses are also shown. The weight losses range from 20% (Mulkey, Pretreatment II) to 64% (Perpetua Head, Pretreatment I). The Si/Al ratios of the material dissolved from the clay samples vary from 0.4 (Hembre, Pretreatment I) to 1.80 (Yaquina Head, Pretreatment II). The theoretical composition of "allophane" given by Jackson (1956, p. 540) has a molar Si/Al ratio of 1. Jackson (1956, p. 528) gives molar Si/Al ratios for unstable "allophane" ranging from 0.25 to 1 and about 1 for stable "allophane". The Si/Al ratios found in "allophanes" forming from volcanic ash generally fall between 0.5 and 1.0 (Yoshinaga, 1965). The Si/Al given for amorphous 2:1 layer silicate relics is 1.5 to 2. The Si/Al ratios of the dissolved constituents fall within the limits given by Jackson (1956) for stable and unstable "allophane" and for amorphous 2:1 layer silicate relics.

The different cleaning procedures used on the soils affected the clay sample weight losses and the Si/Al ratios of the dissolved material. Weight losses were consistently higher and Si/Al ratios were consistently lower for Pretreatment I than for Pretreatment II samples. There are several alternately possible explanations for these difference in weight loss and Si/Al ratios. The three whole-soil C-B-D iron-removal and the Na_2CO_3 treatments may have removed

Table 9. Clay weight losses and extract molar Si/Al ratios from boiling 0.5 $\underline{N}$ NaOH treatment sequences.

	Pretreatment I				Pretreatment II	
Soil and	1:1500, Clay/NaOH		1:1000, Clay/NaOH		1:1000, Clay/NaOH	
Horizon	Wt. Loss	Si/Al	Wt. Loss	Si/Al	Wt. Loss	Si/Al
	%		%		%	
Price Peak						
A12	40.9	.94	39.2	.98	30.2	1.58
B21	42.7	.78	41.9	.83	30.6	.93
B22	46.5	.69	42.1	.73	34.6	.94
Yaquina Head						
A11	41.0	.88	39.2	.88	32.4	1.32
IIA12	38.2	1.18	36.6	1.22	30.3	1.80
IIAC	39.2	.83	40.2	.85	31.9	1.07
IIC	56.4	.77	48.3	.86	34.8	.90
Perpetua Head						
A12	52.0	.96	50.6	.99	34.5	1.67
A13	59.7	.75	59.6	.74	40.0	.89
C	63.9	.71	64.6	.60	50.7	.95
Perpetua Beach						
A12	.49.4	.67	47.9	.76		
B2	51.7	.66	49.5	.72		
Hembre						
A1	40.9	.55	38.9	.58		
A3	40.3	.51	38.9	.55		
B21	52.0	.40	42.4	.43		
Cascade Head						
A11	36.4	.96	35.3	.92		
A12	36.8	.84	35.5	.98		
Tillamook Head						
A(CT-4)	24.8	1.07	23.7	1.07		
A(CT-5)	36.2	.89	34.1	.87		
Mulkey						
A11	23.9	1.04	23.3	1.12	20.4	1.59
A12	26.1	.89	25.6	1.03	20.0	1.05
Quillayute						
A11	33.1	.83	34.0	.82	28.2	1.22
A12	33.8	.72	32.4	.87	26.4	1.05
A13	34.4	.62	33.1	.79	25.8	.99

Table 9. continued

| Soil and Horizon | Pretreatment I | | | | Pretreatment II | |
| | 1:1500, Clay/NaOH | | 1:1000, Clay/NaOH | | 1:1000,Clay/NaOH | |
	Wt. Loss	Si/Al	Wt. Loss	Si/Al	Wt. Loss	Si/Al
	%		%		%	
Camas Prairie						
A	23.6	1.42	23.5	1.45		
C	21.9	1.45	18.4	1.74		
Camas Ridge						
A11	21.0	1.49	22.6	1.42		
A12	19.1	1.49	22.6	1.25		
Molock Beach						
A1	27.6	.83	26.5	.85		
AC	46.6	.54	38.4	.66		
C	50.3	.48	43.3	.51		
Molock Creek						
A1	22.0	1.64	26.4	1.45		
AC	55.5	.69	41.2	.85		

more unstable alumino-silicate from the Pretreatment II samples.

The Si analyses of the C-B-D and Na_2CO_3 extracts (Table 5, p. 46)

do not indicate that this occurred to a significant degree. Also, the

amount of Si dissolved in a particular sample by the boiling NaOH

treatment sequence was relatively constant regardless of the number

of whole-soil iron-removal treatments (Appendix IV). Iron and Mg

extracted by the C-B-D reagents following the boiling NaOH treatment

were very low compared with Al and Si dissolved by the 0.5 $\underline{N}$ NaOH.

Thus, differences in weight losses between Pretreatment I and II

samples mainly appear to be related to differences in amounts of

NaOH soluble Al removed by the different pretreatment procedures.

The larger number of C-B-D cleaning treatments undoubtedly re-

moved more interlayer hydroxy-Al, gibbsite, and probably amor-

phous Al-oxide. As mentioned previously, multiple iron-removal

treatments on the separated Pretreatment I clay samples tended to

remove hydroxy-interlayer material and increase the collapse of K-

saturated samples upon heating and removed gibbsite peaks from

x-ray patterns. The difference in weight loss due to interlayer re-

moval by different numbers of C-B-D pretreatments was probably

minor, however. Based upon experimental evidence (Dixon and

Jackson, 1962) that approximately 1 mmol Al per me of cation ex-

change capacity can be fixed as interlayer $Al(OH)_2^{+2}$, complete inter-

layer removal from clay with 100 me/100 g cation exchange capacity

would amount to a weight reduction of only about 6%. Since hydroxy-interlayer removal was incomplete even after the boiling NaOH treatment sequence, the primary source of differentially dissolved Al, more likely, was either gibbsite or amorphous Al-oxides. The lack of quantitative gibbsite data makes it very difficult to make corrections to arrive at a closer dissolved amorphous alumino-silicate content.

Where the amount of gibbsite in the sample was substantial (Hembre, B21 and Molock Beach, C), greater weight losses and lower Si/Al ratios were obtained with the 1:1500 clay/NaOH suspension (Table 9). This is apparently due to more complete gibbsite removal than with the 1:1000 clay/NaOH suspension. Where gibbsite D.T.A. peaks were small or absent the results were very similar for the two ratios.

The D.T.A. patterns and Si/Al ratios do give some indication of the nature of the dissolved alumino-silicate material. The high Si/Al ratios of dissolved material for most surface samples (Table 9) indicates dissolution of poorly crystalline 2:1 layer silicates or amorphous 2:1 relics. The Si/Al ratio of approximately 1 for the Cascade Head and Tillamook Head (CT-4) samples probably indicates the dissolution of a poorly crystalline kaolin mineral. The presence of amorphous alumino-silicate material with allophane-like properties in the Perpetua Head, Perpetua Beach, and Yaquina Head subsoil

samples is indicated by the Si/Al ratios and D.T.A. patterns. The Perpetua Head D.T.A. pattern is somewhat similar to D.T.A. patterns of imogolite reported by Yoshinaga (1965).

The presence of amorphous material is also indicated by cation exchange capacity measurements with neutral salt solutions (Appendix V). The clay samples in which chloritic intergrade predominates (all samples except Tillamook Head (CT-4), Mulkey, Camas Prairie, Camas Ridge, and Molock Creek Al) would be expected to have low cation exchange capacities. The cation exchange capacities of all the clay samples are above 40 me/100 g. The Perpetua Head subsoil samples are over 100 me/100 g.

Although some amorphous material may have formed from volcanic ash in the soils in the study, the amount is probably relatively small. A smectite-type clay appears to be a first-weathering product of the basaltic rock in the soils studied. The main part of the amorphous materials appearing in the soils of basaltic origin probably results from ions in excess of that required for clay formation and then dissolution or decomposition of the clay under the extremely acidic conditions.

Summary of Clay-Sized Mineral Components

The summary of the clay-sized mineral components identified is given in Table 10. The suite is presented on a minimal

Table 10. Summary of clay-sized fraction components and estimates of relative occurrence in individual (Pretreatment I) soils.

Soil	[1]Amor. %	Gb. Rel. Peak Ht.	Chl.Int.	Chl.	Sm.	Vm.	Mica	Kl.	Qtz.	Fld.	Amph.
Price Peak	41-46	2-6	D	P	P	P	M	?	M	-	-
Yaquina Head	38-56	<1-2	D	P	P	P	M	?	M	M	-
Perpetua Head	52-64	<1-1	D	M	P	P	M	?	M	-	-
Perpetua Beach	49-52	1	D	P	P	P	M	?	M	M	-
Hembre	40-52	11-18	D	P	P	P	M	?	M	-	-
Cascade Head	36-37	0	D	M	P	M	-	P	M	-	-
Tillamook Head (CT-4)	25	1	P	M	P	P	M	P	M	-	-
(CT-5)	36	5	D	M	P	P	M	P	M	-	-
Mulkey	24-26	3-4	P	P	P	P	P	P	M	M	P
Quillayute	33-34	3-4	D	P	P	P	M	?	M	-	-
Camas Prairie	22-24	0	P	M	D	-	M	?	M	-	-
Camas Ridge	23	0	P	M	D	-	M	?	M	-	-
Molock Beach	28-50	7-11	D	P	P	P	M	?	M	-	-
Molock Creek	26-55	<1-7	P-D	M	P	P	M	?	M	-	-

[1] Amor. = amorphous material plus gibbsite; Gb. = gibbsite; Chl.Int. = chloritic intergrade; Chl. = chlorite; Sm. = smectite; Vm. = vermiculite; Mica = (illite); Kl. = kaolin; Qtz. = quartz; Fld. = feldspar; Amph. = amphibole; D = dominant; P = present (no quantitative significance); M = minor (<5%); ? = possibly present.

pretreatment basis, thus representing what is believed to be essentially organic matter and Fe-oxide-free conditions. The percent amorphous material (Amor.) listed is the range in maximum weight losses obtained on Pretreatment I samples within the profile. The weight loss due to gibbsite dissolution is included. The presence of gibbsite in the samples is denoted by a "relative peak height" (Rel. Peak Ht.) number ranging from 0 (absent) to 18. The qualitatively dominant (D) phyllosilicate component considered to be present "in situ" is listed. No quantitiative significance can be given to the presence (P) of smectities, vermiculite and chlorite in the majority of the cases because of the dominance of chloritic intergrade material in most of the soils. Minor (M) components listed are those which appear to make up less than 5% of the samples.

Classification of the Soils

The nomenclature for classifying soils according to the Com-
prehensive Soil Classification System (Soil Survey Staff, 1960) con-
sists of placing the soil into established orders, suborders, great
groups, and subgroups for higher categories. Supplemental materials
pertinent for classifying the soils in this study are given in "Supple-
ment to Soil Classification System (7th Approximation)" (Soil Survey
Staff, 1967). Some of the soils in the study cannot be classified
completely with the present data because all horizons were not sam-
pled.

Order

The soils in the study meet the criteria for being placed in the
Inceptisol order (Soil Survey Staff, 1967, p. 89) in that they are
mineral soils that have no spodic, argillic, or oxic horizons and do
not contain plinthite within 30 cm of the mineral surface. The soils
are usually moist between 18 and 50 cm more than one-half of the
time and have a mean annual soil temperature greater than 8° C.
The soils are extensively leached with conductivities of saturated
extracts less than 2 mmhos/cm throughout the profile. All the soils
have umbric epipedons in which base saturation is less than 50%.
Only two soils (Price Peak and Hembre) appear to have a cambic

horizon. In these soils most of the original rock has been consider-
ably altered to 2:1 type clay but rock fragments have not been com-
pletely destroyed. Some still-weatherable feldspars and heavy
minerals remain in the sand and silt separates.

Suborder

Criteria for placing Inceptisols in the Andept suborder are:
(1) soils having either or both: (a) more than 60% vitric volcanic ash,
cinders, or other vitric pyroclastic material in the silt, sand and
gravel fractions; (b) a bulk density of the fine earth fraction of the
soil less than 0.85 g/cc in the epipedon or the cambic horizon, or
both, and the exchange complex dominated by amorphous material;
(2) soils not saturated with water at any period or lack characteristics
associated with wetness defined for Aquepts; and (3) soils lacking a
plaggen epipedon (Soil Survey Staff, 1967, p. 89).

The soils in the study cannot be placed in the Andept suborder
on the basis of vitric volcanic ash, cinders, or other vitric pyro-
clastic material content in the silt or sand fractions. However, all
the soils in the study do contain small amounts of volcanic ash. The
maximum "total soil volumetric percentage" of dacitic glass (obtained
by the addition of: separate weight percentage x light fraction
weight percentage x glass count percentage for the fine sand, very
fine sand, and coarse silt in each horizon) was found in the A12

horizon of the Price Peak soil and amounted to 1.6%. All other soils

contained lesser percentages. Expressed on the basis of the glass

count in each separate of the Price Peak A12, the percentages

ranged between 5 and 7% (Appendix III, Table 3b). A higher total

volcanic ash percentage could be obtained by including the feldspar,

pyroxenes, and hornblende associated with the glass which qualifies

technically as solid pyroclastic ejecta. However, except where glass

sheaths occurred on the crystalline minerals, no way was found to

critically differentiate these minerals from non-pyroclastic sources.

Even if the crystalline pyroclastic ejecta was included, the total

amount of ash in the soils would fall far short of the 60% threshold

value.

The Yaquina Head soil was developed primarily from a glassy

(devitrified) basaltic dike rock. The percentage unaltered rock in

the sand and gravel fraction would be far less than 60.

Many of the soils in the study have bulk densities lower than

0.85 g/cc in the umbric epipedon (Table 3) and, therefore, could be

placed in the Andept suborder.

A very broad definition of "amorphous material" is given by

the Soil Survey Staff (1967, p. 36). The amorphous material, as

defined, not only includes allophane and allophane-like material but

also material amorphous to x-rays which is associated with O.M.

containing Al. Empirical methods are used to determine "domination

of the cation exchange complex by amorphous material" in the

Comprehensive Soil Classification System. Conditions to be satisfied

when "amorphous material dominates an exchange complex" are:

(1) a very high exchange capacity of the measured clay (at pH 8.2)

(more than 150 me/100 g measured clay, and commonly more than

500 me/100 g); (2) if there is enough clay to have a 15-bar water

content of 20% or more, the pH of 1 g of soil in 50 ml of 1$\underline{N}$ NaF is

more than 9.4 after 2 minutes; (3) the measured clay/15-bar mois-

ture retention ratio is less than 1; (4) the O.M. exceeds 1%; and (5)

D.T.A. shows a low temperature endotherm (Soil Survey Staff, 1965,

p. 36).

These measurements for determining whether or not the ex-

change complex of the soil was dominated by amorphous material are

given in Table 11. The "apparent" (App.) CEC/100 g clay was

calculated using whole-soil CEC values (Table 3) and Pretreatment I

clay percentages (Table 4). All the surface samples, except the

Camas Prairie and Camas Ridge soils, show values greater than 150

indicating domination by amorphous materials. In general, the values

decrease with depth whereas amorphous material as measured by

NaOH dissolution increases with depth. It is probable that the CEC

of surface horizons of the soils is more influenced by O.M. than

amorphous material. The CEC of the clay samples in unbuffered

neutral salts was less than 150 me/100 g. The CEC of the clays at

Table 11. Measurements used for determining domination of the cation exchange complex by amorphous material.

Soil and Horizon	*App.CEC/ 100 g Clay	pH (1 N NaF)	15-Bar Moisture	Clay/ 15-Bar	CEC/ 15-Bar
			%		
Price Peak					
A12	350	9.8	39.6	0.71	2.5
B21	255	10.3	26.3	0.99	2.6
B22	200	10.4	20.8	1.04	2.1
Yaquina Head					
A11	395	10.3	19.9	0.71	2.8
IIA12	262	10.1	38.7	0.96	2.5
IIAC	278	11.0	29.1	0.90	2.5
IIC	173	11.0	32.5	1.10	1.9
Perpetua Head					
A12	290	11.3	37.1	0.75	2.2
A13	170	11.3	29.9	1.31	2.3
C	160	10.9	19.0	2.06	3.3
Perpetua Beach					
A12	240	11.0	27.8	0.90	2.2
B2	240	11.0	27.3	0.95	2.3
Hembre					
A1	205	10.1	34.8	0.94	2.0
A3	185	10.8	33.6	0.92	1.7
B21	165	10.4	33.6	0.84	1.4
Cascade Head					
A11	160	10.9	33.7	1.05	1.7
A12	160	11.3	31.9	1.13	1.8
Tillamook Head					
A(CT-4)	157	9.6	35.1	1.43	2.3
A(CT-5)	225	11.3	37.8	1.14	2.6
Mulkey					
A11	400	10.1	23.1	0.58	2.4
A12	295	10.9	20.3	0.68	2.0
Quillayute					
A11	220	10.9	33.0	0.96	2.1
A12	225	11.2	32.3	0.98	2.2
A13	195	11.4	30.4	1.10	2.1
Camas Prairie					
A	105	10.0	34.7	1.70	2.0
C	75	10.1	33.3	2.07	1.6

Table 11. continued

Soil and Horizon	*App.CEC/ 100 g Clay	pH (1 N NaF)	15-Bar Moisture	Clay/ 15-Bar	CEC/ 15-Bar
Camas Ridge					
A11	105	10.4	40.2	1.56	1.7
A12	85	10.7	38.7	1.60	1.5
Molock Beach					
A1	210	10.2	34.4	0.95	2.0
AC	140	11.4	26.5	1.19	1.7
C	100	11.6	31.5	1.16	1.2
Molock Creek					
A1	190	8.6	25.3	1.49	2.9
AC	125	11.4	28.5	1.54	2.0

*Apparent CEC/100 g Clay

pH 8.2 was not determined. Since hydroxy-Al interlayer material can cause a pH-induced increase in CEC (deVilliers and Jackson, 1967), it was felt that such a measurement would be misleading in the soils in which chloritic intergrade clay is the dominant type. The pH difference in CEC measured at pH 7 and 8.2 was intended to reflect the pH-dependency of "allophane"(Soil Survey Staff, 1967, p. 36).

The pH determined in 1 $\underline{N}$ NaF is greater than 9.4 for all the samples in the study, except the Molock Creek Al. Thus, under this criteria nearly all the soils could be placed in the Andept suborder. The exchange complex of soil samples, such as the Camas Prairie C or the Mulkey series, clearly are not dominated by amorphous material as determined by NaOH dissolution. The high pH produced in 1 $\underline{N}$ NaF in these soils is no doubt partially due to the adsorption of F^- by complexed Al, Fe- and Al-oxides, or gibbsite. The pH of gibbsite nodules in the 1 $\underline{N}$ NaF was over 10.

The other condition to be met is that the ratio of the measured clay (%)/15-bar moisture retention(%) be less than one . In general, the 15-bar moisture retention (Table 11) decreases with depth whereas the clay content changes little with depth. However, the amorphous material as measured by 0.5 $\underline{N}$ NaOH dissolution in-creases with depth. This might be due to some irreversible dehydra-tion of amorphous materials caused by air-drying the samples. On

the other hand, the higher moisture retention in the surface horizons may merely be due to retention by O.M. In general, the clay/15-bar retention ratio also increased with depth. The Perpetua Head soil with the highest amorphous material content (Table 10) would be eliminated from the Andept suborder on the basis of these low moisture retention values in the A13 and C horizons if it were not for the strong D.T.A. dehydration endotherms. The clay/15-bar retention ratio of horizons near the surface of most of the soils formed from crystalline or vitric basaltic rock are less than one. The Mulkey series samples weathered from contact metamorphic rock (with a low NaOH soluble amorphous material content) exhibits the lowest ratio. The soils formed from sedimentary rock or sedimentary alluvium (Tillamook Head, Camas Prairie, Camas Ridge, Molock Beach, and Molock Creek) generally exhibit ratios greater than one.

Although the data relating to domination by amorphous material are not completely consistent throughout the umbric epipedon, the soils formed from basic igneous rock, alluvium consisting largely of basic igneous rock (Quillayute), and contact metamorphic rock (Mulkey) were tentatively placed in the Andept suborder. The Hembre, Cascade Head, and Mulkey soils are considered to have minimal properties. The soils of sedimentary origin, were not placed in the Andept suborder. The Molock Beach soil was not placed there

because the A1 horizons, which would qualify, only represents about one-third of the umbric epipedon.

The next closest suborder that the soils of sedimentary origin would be apt to fit is the Umbrept (Soil Survey Staff, 1967, p. 107). One of the definitions for an Umbrept is that it "have an exchange complex that is dominated by crystalline alumino-silicate clay minerals". This could be interpreted ambiguously because O. M. together with amorphous material might represent a higher total negative charge than that of the crystalline clay.

Great Group

The soils placed in the Andept suborder would all fit under the Dystrandept great group. The properties placing these soils in this great group are: (1) an umbric epipedon and a whole-soil 15-bar water retention greater than 20% between 25 and 100 cm or a lithic contact; (2) soil temperatures warmer than Cryandepts (>8° C); (3) clays that do not dehydrate irreversibly into gravel-sized aggregates; and (4) no duripan (Soil Survey Staff, 1965, p. 90).

The soils placed in the Umbrept suborder fit under the Hap-lumbrept great group. The properties placing them in this great group are (1) umbric epipedon; (2) soil temperatures warmer than Cryumbrepts; (3) no fragipan; and (4) not dry for as much as 60 days in all subhorizons between 18 and 50 cm.

Subgroup

The proposed subgroup classifications are included in Table 12. The Dystrandept great group soils were placed in the Typic subgroup because they: (1) lack mottles with chromas less than 2; (2) have umbric epipedons thicker than 25 cm; (3) lack a lithic contact within 50 cm of the surface; (4) have CEC values more than 30 me/100 g in all horizons; and (5) do not exhibit good thixotropic properties. Although the "smeary" property ascribed to soils of this group has been described as thixotropy (Soil Survey Staff, 1967, p. 42), a reversible gel-sol reaction did not appear to take place in clay-water suspensions. The separated clays do not form a gel as a non-hydroxy-interlayered montmorillinitic clay does. The smeary consistence appears to be partly related to high soil O.M. content and partly to resistance of aggregates to breakdown.

The Haplumbrept soils were placed in the Andic subgroup because (1) the bulk densities of all horizons sampled were less than 0.95 g/cc (Table 3); (2) CEC/15-bar moisture ratios were greater than 1.5 in the umbric epipedon; and (3) the Molock Beach clay/15-bar moisture ratios was less than 1.25 (Table 11). The clay/15-bar moisture ratios of the Camas Prairie, Camas Ridge, and Molock Creek soils were greater than 1.25 which would exclude them from the Andic subgroup. However, these soils were placed in the Andic

Table 12. Proposed classifications

Soil	Classification
Price Peak	Typic Dystandept
Yaquina Head	Typic Dystrandept
Perpetua Head	Typic Dystrandept
Perpetua Beach	Typic Dystrandept
Hembre	Typic Dystrandept
Cascade Head	Typic Dystrandept
Mulkey	Typic Dystrandept
Quillayute	Typic Dystrandept
Camas Prairie	Andic Entic Haplumbrept
Camas Ridge	Andic Cumulic Haplumbrept
Molock Beach	Andic Cumulic Haplumbrept
Molock Creek	Andic Cumulic Haplumbrept

subgroup on a "best-fit" basis. These three soils have other aberrant properties which warrant excluding them from the Typic subgroup. The aberrant properties are lack of a cambic horizon and O.M. contents greater than 0.5% within 1.25 m from the soil surface. The Camas Ridge, Molock Beach, and Molock Creek soils were also placed in the Cumulic subgroup category because each has an umbric epipedon more than 50 cm thick.

Suggestions for Classification Improvement

The determination of 15-bar moisture percentages and CEC on peroxidized samples which were not allowed to dry-out before analysis would help to clarify questions concerning possible amorphous material dehydration effects and the influence of O.M. on CEC and moisture retention. These determinations might give more reliable indications of "domination of amorphous mineral material" than comparable measurements on unperoxidized samples. Selective alkali dissolution treatments on peroxidized whole soils (those with low plant opal contents) might be useful for correlation studies of amorphous material determined by moisture and CEC measurements with those determined by dissolution techniques. These measurements would be most applicable on soils weathering from volcanic rock in which substantial amounts of lithic fragments containing clay are not completely dispersed.

The addition of a "Haplumbreptic" subgroup or intergrade to the Dystrandept great group would be useful for distinguishing Andepts formed from basic igneous rock or other non-pyroclastic material from those principally formed from volcanic ash or other vitric pyroclastics. Although eight of the soils appear to fit under the Typic Dystrandept category, the clay mineralogy is not very typical of Andepts formed from volcanic ash.

SUMMARY AND CONCLUSIONS

Soil samples were collected from 13 sites in western Oregon which had characteristics similar to soils formed on volcanic ash in Japan, New Zealand, and other parts of the world. The soils were characterized chemically and physically and the sand, silt, and clay mineralogy was determined.

The soils in the study have many of the properties normally associated with the "classical" Andosols of Japan and New Zealand. These properties, exhibited in varying degrees, include high O.M. content, low bulk density, low pH and base saturation, Al complexed by soil humus, high anion adsorption capacity, and the presence of amorphous material. The surface horizon O.M. content of five soils exceeded 30%. The lowest O.M. content for surface horizons was 14%. The O.M. content of all subsoils tended to be high. The least subsoil O.M. content was 4%. Carbon/nitrogen ratios varied from 13 to 32. The higher C/N ratios were found on forested or formerly forested soils. Bulk densitites of most of the surface horizons were low (about 0.6-0.8 g/cc). It was concluded that this was mainly due to unusually high O.M. contents. The pH in 1:1 water suspensions ranged from strongly acid to very strongly acid (5.3-3.8). Base saturation varied from 1 to 30%. The base saturation of the majority of the samples was 10% or less.

Considerable Al was found to be complexed by the humic fractions of the five soils on which these analyses were performed. A linear relationship was found when Al extracted during peroxidation was related to crude humate extracted with 0.3 $\underline{N}$ NaOH. High soil anion adsorption capacity in most of the samples was indicated by high pH values in 1 $\underline{N}$ NaF suspensions. The weight loss of clay samples and Si/Al ratios of the dissolved substance from boiling 0.5 $\underline{N}$ NaOH dissolution sequences were used to evaluate the amorphous materials in the samples. Weight losses of clays with minimal pretreatment (1 C-B-D iron-removal pretreatment) ranged from 18 to 64%. In some cases, these weight loss values include dissolved gibbsite. A clear-cut distinction between amorphous alumino-silicate mineral and free Al-oxides was not obtained with the dissolution treatments used. Little direct evidence was found that indicated the dissolved alumino-silicate material was a "gel-like allophane" usually formed in volcanic ash soils. The Si/Al ratios and D.T.A. patterns of clay samples from sub-horizons of three soils approached those of allophane, however.

The results of the sand and silt mineralogy studies show that the soils have developed without the presence of significant quantities of volcanic ash as a parent material. The sites sampled included soils formed from or over basalt, a contact metamorphic rock, sedimentary rock, and alluvium derived from sedimentary rock and

volcanic rock. However, all soil samples contained small amounts of dacitic glass shards. Soils developed on sediment or sedimentary rock formations, mapped as possibly containing tuffaceous materials, were found to contain only trace amounts of pumiceous shards. On the basis of R.I. determinations and the presence of glass-sheathed plagioclase, pyroxene, and hornblende in the samples, it was concluded that most of the volcanic ash originated from Mt. Mazama. Although some amorphous alumino-silicate may have formed in the soils due to the presence of small amounts of volcanic ash, the amount is probably relatively small. Eolian materials were common in soil samples taken on the Oregon coast.

Thin sections of little-weathered basaltic rock and saprolite also revealed variations in the crystallinity of the rocks from which some of the soils were formed. Thin sections of the rock at the Yaquina Head site showed a basaltic glass (devitrified) origin. Basic volcanic glass and palagonite were found in the sand and silt fractions of this soil. The Perpetua Head basaltic rock was highly porphyritic with a very fine-grained matrix. Thus, a number of parent materials varying in mineralogical properties appear to have been involved in the formation of the soils.

Other notable features were found in the petrographic studies. Large percentages of the light fraction mineral grains of soils formed mainly from basic igneous rock were found to be highly weathered

lithic fragments whose weathering products were unidentifiable with the petrographic microscope. X-ray diffractograms of these grains revealed peaks for 2:1 layer type clay minerals. Zeolites were identified in soils formed from basalts and sparingly in soils of sedimentary origin. Plant opal was found in every soil; the coarse silt fraction of the Perpetua Head soil contained up to 22%. Plant uptake of Si would retard pedogenic clay formation. It was concluded that a high opal content in subsoil depths was probably a good indication of past colluvial activity when trying to diagnose whether O.M. accumulated in subsoils was colluvial or illuvial in nature.

The clay mineral suites of the soils were complex. Chloritic intergrade (aluminous chlorite) was considered to be the predominant crystalline phyllosilicate mineral in the sample of ten sites. Montmorillinite was dominant in two soils and mica plus vermiculite was dominant in one soil. Smectite clay was present in all samples but the specific type could not be determined in the majority of cases. Chlorite was present in all samples in trace to moderate amounts. Vermiculite was considered to be present or possibly present in all sites but two. A substantial amount of mica was present in the clays of only one soil. The presence of a kaolin mineral was believed to be reasonably certain in the clays of three sites. The presence or absence of kaolin could not be established in all the other sample sites because possible 7 Å kaolin x-ray diffraction peaks were

confounded by second-order 7 Å chlorite peaks. Minor amounts of quartz were found in the clays of all sites. Feldspar was present in the clays of three sites and an amphibole was present in clay of one site.

All soils fit into the Inceptisol order under the U.S.D.A. Comprehensive Soil Classification System. Eight soils were tentatively placed in the Typic Dystrandept category. The tentative status was made because it was felt that O.M., per se, may have had a significant influence on the measures used to determined "domination of the exchange complex by amorphous material". The predominate parent materials of these soils were basaltic rock, alluvium derived from basic igneous rocks, and a granophyric diorite rock. The most pronounced Andepts in this group tended to be associated with the finer rock textures and relatively unweathered parent material. Three soils were classified as Andic Cumulic Haplumbrepts and one as an Andic Entic Haplumbrept. The predominant parent material of these soils was sedimentary in origin.

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APPENDICES

APPENDIX I

Table 1. Profile descriptions of sample sites.

<u>Price Peak</u>

Described by: Roger Parsons (1963)

Location: NW$\frac{1}{4}$ of SE$\frac{1}{4}$ Sec. 36, T10S, R6W

Hor-izon	Depth		Description
	cm.	in.	
A11	0-13	0-5	Black (10 YR 2/1) loam; weak very fine granular structure, very friable; 55% 1/4 to 2 in. subangular basalt gravel; soil material has very low bulk density; abundant fine roots; gradual wavy boundary.
A12	13-23	5-9	Black to very dark brown (10YR 2/1.5) loam; moderate very fine subangular blocky structure; very friable; 65% 2 to 4 in. basalt gravel and cobbles.
B21	23-46	9-18	Dark reddish brown (5YR 3/4) clay loam; strong very fine granular structure; very friable; 80% subangular basalt cobbles with yellowish red (5YR 4/6) clay films; very low bulk density; gradual wavy boundary.
B22	46-76	18-30	Dark reddish brown (5YR 3/4) clay loam; strong very fine granular structure, very friable; 80% subangular basalt gravel and cobbles with thin yellowish red (5YR 4/6) clay films; very low bulk density; abrupt irregular boundary.
IIR	76-91	30-36	Fractured, relatively unweathered angular basalt bedrock.

Yaquina Head

Described by: Ellis G. Knox (10/25/63)

Location: SW¼ of NW¼ Sec. 30, T10S, R12W

Hor-izon	Depth cm. in.		Description
A11	0-10	0-4	Very dark brown (10YR 2/3, moist) loam; weak very fine granular structure; very friable, slightly plastic, slightly sticky; lower boundary abrupt and smooth. This is a recent wind deposit.
IIA12	10-46	4-18	Black (10YR 1/2, moist) silt loam or silty clay loam; moderate very fine and fine subangular blocky breaking to strong very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many fine interstitial pores; 10% coarse fragments; lower boundary gradual and wavy.
IIAC	46-112	18-44	Dark brown (10YR 3/3, moist) silt loam or silty clay loam; weak very fine subangular block breaking to moderate very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many very fine interstitial pores, common very fine tubular pores; 10% coarse fragments; lower boundary clear and wavy.
IIC	112+	44+	Dark yellowish brown (10YR 3/4, moist) silt loam or silty clay loam; moderate very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many very fine tubular pores; 10% coarse fragments.

Coarse fragments are mostly subangular, fine pebbles of basalt.

Perpetua Head

Described by: Ellis G. Knox (10/25/63)

Location: About 30 feet downslope of Cape Perpetua view-point park-
ing lot. SW¼ of NE¼ Sec. 3, T15S, R12W

Hor-izon	Depth		Description
	cm.	in.	
A11	0-5	0-2	Black (5YR 1/2, very moist) silt loam or silty clay loam; strong very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many interstitial pores; lower boundary abrupt and wavy (may be only a wetting front).
A12	5-43	2-17	Dark reddish brown (5YR 2/2, moist) silt loam or silty clay loam; moderate fine and very fine subangular blocky breaking to moderate very fine granular structure; very friable but brittle, slightly plastic slightly sticky, smeary; many interstitial pores, common very fine tubular pores.
A13	43-81	17-32	Very dark brown (7.5YR 2/2, moist) silt loam or silty clay loam; moderate very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many very fine interstitial pores, few very fine tubular pores; intermixed with material and horizon below; lower boundary gradual and irregular.
C1	81-122+	32-48+	Dark brown (7.5YR 3/3, moist) silt loam or silty clay loam; moderate very fine granular structure; very friable, slightly plastic, slightly sticky, smeary; many very fine interstitial pores, few fine tubular pores; includes 20-30% of material as dark as A13.

About 5% subangular pebbles of basalt below 24 in., perhaps with a
maximum at 24 in.

Perpetua Beach

Described by: W. T. Franklin (7/5/63)

Location: At about 30-foot elevation above ocean, about 100 feet downslope of highway, south of bridge directly below Cape Perpetua viewpoint. SW$\frac{1}{4}$ of SE$\frac{1}{4}$ Sec. 3, T15S, R12W

Hor-izon	Depth cm.	in.	Description
A11	0-13	0-5	Black (10YR 2/1) loam or fine sandy loam; moderate to strong very fine granular structure, very friable, slightly plastic, slightly sticky; abundant fine roots; abrupt wavy boundary.
A12	13-25	5-10	Very dark brown (10YR 2/2, moist) loam; moderate very fine granular structure; very friable, slightly plastic, slightly sticky; lower boundary smooth and gradual.
B2	25-38	10-15	Dark reddish brown (5YR 2/2, moist) loam; weak very fine subangular blocky structure; friable, slightly plastic, slightly sticky; lower boundary gradual and irregular.
C	38-81	15-32+	Dark yellowish brown (10YR 3/4, moist) loam or silt loam; friable, slightly plastic, slightly sticky.

Hembre

Location: SE$\frac{1}{4}$ of SE$\frac{1}{4}$ Sec. 23, T1N, R8W

Hor-izon	Depth cm.	in.	Description
A1	0-13	0-4	Dark reddish brown (5YR 3/2, moist) silt loam; strong very fine and fine granular structure; soft, very friable, non-sticky, slightly plastic; many roots; many fine pores; fine and medium shot common; clear smooth boundary.

Hor-izon	Depth cm.	in.	Description
A3	13-28	4-11	Dark brown (5YR 3/3, moist) silt loam; strong very fine and fine granular structure; soft, friable, slightly sticky, slightly plastic; many roots; many fine pores; fine and medium shot common; clear wavy boundary.
B21	28-56	11-17	Dark brown (7.5YR 3/2, moist) silt loam or silty clay loam; weak very fine and fine sub-angular blocky structure breaking to moderate very fine granular; soft, friable, slightly sticky, slightly plastic; many roots; few medium shot; clear smooth boundary.
B22	56-74	17-29	Reddish brown (5YR 4/3, moist) silty clay loam; weak medium subangular blocky structure breaking to moderate, very fine sub-angular blocky; hard, firm, sticky, plastic; thin, continuous clay films; few cobbles and stones; clear wavy boundary.
B3	74-98	29-38	Reddish brown (5YR 4/4, moist) very stony silty clay loam; moderate, very fine and fine subangular blocky structure; hard, firm, sticky, plastic; thin nearly continuous clay films; about 60% stones; abrupt irregular boundary.
R	98+	38+	Basic igneous rock.

Cascade Head

Described by: W. T. Franklin

Location: Road-cut, south-facing slope, near highest point on Cascade Head. NE$\frac{1}{4}$ of SW$\frac{1}{4}$ Sec. 12, T5S, R11W

Hor-izon	Depth cm.	Depth in.	Description
A11	0-28	0-11	Dark brown (7.5YR 3/2, moist) silt loam; strong fine to very fine granular structure; very friable, slightly plastic, non-sticky; abundant fine roots and many charcoal fragments; smooth gradual lower boundary.
A12	28-66	11-26	Dark brown (7.5YR 3/2, moist) silt loam; moderate very fine subangular blocky structure; very friable, slightly plastic, slightly sticky; common reddish shot and about 10% highly weathered fine basalt fragments.
C	66-122+	26-48+	Yellowish brown (10YR 5/4, moist) silt loam or silty clay loam; weak very fine granular structure; friable, slightly plastic, slightly sticky; highly weathered basalt fragments increasing with depth.

Tillamook Head

Location: SW¼ of NW¼, Sec. 18, T5N, R10W

Horizon	Color Dry	Moist
A(CT-4)	Dark brown 10YR 3/3	Black to dark reddish brown (5YR 2/1.5)
A(CT-5)	Dark reddish brown 5YR 3/3	Dark reddish brown (5YR 2/2)

Mulkey

Described by: W. T. Franklin

Location: About 300 feet downslope of road at the summit of Mary's Peak on north-facing slope in grassy area. NE¼ of SW¼ Sec. 21, T12S, R7W

Hor-izon	Depth cm.	in.	Description
A11	0-25	0-10	Black (10YR 2/1, moist) loam; moderate to strong very fine granular structure; very friable, slightly plastic, slightly sticky; abundant fine roots; 15% 1 to 2 in. gabbro gravel.
A12	25-51	10-20	Very dark brown (10YR 2/2, moist) loam; weak very fine subangular blocky breaking to moderate very fine granular structure; very friable, slightly plastic, slightly sticky; common fine roots; 10% 1 to 2 in. angular to subangular gabbro gravel.
AC	51-97	20-38	Dark brown (10YR 3/3, moist) loam; moderate to weak very fine subangular blocky structure; friable, slightly plastic, slightly sticky; 20% gravel and cobbles.
C	97-117+	38-46+	Dark yellowish brown (10YR 4/4, moist) loam; weak very fine granular structure; friable, slightly plastic, slightly sticky; gravel and cobbles increasing with depth.

Quillayute

Described by: W. T. Franklin (7/6/63)

Location: Samples and description taken from cut of excavation for Odd Fellows Crematorium, Tillamook, Ore. SW$\frac{1}{4}$ of NW$\frac{1}{4}$ Sec. 30, T1S, R10W.

Hor-izon	Depth cm.	in.	Description
A11	0-20	0-8	Black to very dark brown (10YR 2/1.5, moist) silt loam or silty clay loam; strong very fine granular structure; very friable, slightly plastic, slightly sticky; abundant fine roots; lower boundary clear and smooth.

Hor- izon	Depth		Description
	cm.	in.	
A12	20-30	8-12	Black (10YR 2/1, moist) silt loam; moderate to weak fine and very fine granular structure; very friable, slightly plastic, non-sticky; common fine roots; lower boundary gradual and smooth.
A13	30-71	12-28	Black (10YR 2/1, moist) silt loam; weak very fine subangular blocky structure; very friable, slightly plastic, non-sticky; lower boundary irregular.
AC	71-89	28-35	Admixture of black-colored horizon above and yellowish brown material below. May represent discontinuity.
C	89+	35+	Yellowish brown (10YR 5/8, moist) silty clay loam intermixed and stratified with sub-rounded gravel.

Camas Prairie

Described by: W. T. Franklin (6/24/63)

Location: SE$\frac{1}{4}$ of NW$\frac{1}{4}$ Sec. 30, T9S, R10W

Hor- izon	Depth		Description
	cm.	in.	
A	0-30	0-12	Black (10YR 2/1, moist) clay loam; strong very fine to fine granular structure; friable, plastic, somewhat sticky; abundant fine roots and few coarse roots; lower boundary smooth and gradual.
C	30-81+	12-32+	Dark yellowish brown (10YR 3/4, moist) clay loam; plastic, sticky; common red shot.

Relatively recent alluvium on small alluvial fan.

Camas Ridge

Described by: W. T. Franklin (6/24/63)

Location: NE¼ of NE¼ Sec. 30, T9S, R10W

Hor-
izon

A11	0-30	0-12	Black to very dark brown (10YR 2/1.5, moist) silty clay loam; strong very fine granular structure; friable, plastic, slightly sticky; abundant roots and charcoal; lower boundary gradual and smooth.
A12	30-69	12-27	Very dark brown (10YR 2/3, moist) silty clay loam or silty clay; weak very fine granular structure, friable, plastic, slightly sticky; few fine roots; lower boundary gradual and wavy.
C1	69-97	27-38	Dark yellowish brown (10YR 4/5, moist) silty clay; weak very fine subangular blocky structure; plastic, sticky.
C2	97+	38+	Fractured weakly consolidated siltstone or claystone.

Molock Beach

Described by: W. T. Franklin (6/12/63)

Location: Cut overlooking Molock Beach, approximately 5 miles north of Newport, Oregon. SW¼ of NE¼ Sec. 17, T10S, R11W

Hor- izon	Depth		Description
	cm.	in.	
A1	0-23	0-9	Black to very dark brown (10YR 2/1.5, moist) silt loam or silty clay loam; strong fine to very fine granular structure; very friable, slightly plastic, slightly sticky; abundant fine roots and charcoal; lower boundary gradual and smooth.
AC	23-56	9-22	Very dark brown (10YR 2/3, moist) silty clay loam; moderate very fine granular structure; friable, slightly plastic, slightly sticky; few fine roots and charcoal; lower boundary gradual and smooth.
C1	56-127	22-50	Dark yellowish brown (10YR 4/4, moist) silty clay loam; weak very fine granular structure; friable, somewhat plastic, somewhat sticky; lower boundary abrupt, beginning of another stratified layer differing little from C1.

This is a very deep (40-50 feet) and complicated profile, showing many stratified layers, some deep horizons cemented with Fe-oxide, common "Fe-shot" in deeper parts of the profile; and common white nodules in deeper parts of the profile; samples of white nodules taken at about 12- to 15-foot level.

Molock Creek

Described by: W. T. Franklin (6/20/63)

Location: Summit of ridge, south-facing slope, 2.6 miles up Molock Creek road. SW¼ of SE¼ Sec. 15, T10S, R11W

Hor- izon	Depth		Description
	cm.	in.	
O2	8-0	3-0	Very dark brown (10YR 2/2, moist) organic layer.

Hor- izon	Depth cm.	in.	Description
A1	0-30	0-12	Black to very dark brown (10YR 2/1.5, moist) silt loam or silty clay loam; strong very fine granular structure; very friable, slightly plastic, slightly sticky; abundant roots and charcoal.
AC	30-61	12-24	Dark brown (7.5YR 3/2, moist) silty clay loam; moderate to weak very fine granular structure; friable, slightly plastic, slightly sticky; common fine roots; lower boundary gradual.
C1	61-86	24-34	Dark yellowish brown (10YR 4/4, moist) silty clay loam; friable, somewhat plastic, slightly sticky; 20% 1 to 2 in. subangular highly weathered fragments of claystone or siltstone.
C2	86+	34+	Fractured claystone or siltstone.

Table 2. Mechanical analyses of soil samples given Pretreatment II.

Hor-izon	Gr. >2.0	V.C.S. 2-1	C.S. 1-.5	M.S. .5-.25	F.S. .25-.1	V.F.S. .1-.05	C.Si. .05-.02	M.Si- .02-.005	F.Si. .005-.002	C. <.002	Tex-ture
				mm				mm		mm	
Price Peak											
A12	75.6	12.1	7.3	3.4	6.6	6.2	17.2	16.8	5.5	24.9	L
B21	64.2	11.0	6.6	3.1	6.2	6.4	16.6	19.2	5.0	25.9	L
B22	56.5	8.0	7.2	3.9	7.3	6.8	16.6	19.5	5.3	25.4	L
Yaquina Head											
A11	4.0	0.6	2.8	35.4	26.2	6.3	5.4	6.7	2.7	13.9	SL
IIA12	18.1	1.6	4.8	8.6	13.3	7.4	9.4	14.9	5.1	34.9	CL
IIAC	27.4	3.5	6.3	9.3	13.2	7.5	9.4	15.6	5.8	29.4	CL
IIC	35.2	1.6	5.1	7.7	11.5	7.4	9.5	18.4	6.8	32.0	CL
Perpetua Head											
A12	33.7	3.1	5.2	4.0	11.0	8.6	15.3	20.5	3.3	29.0	CL
A13	34.6	2.4	4.5	3.6	10.2	8.9	15.9	18.5	3.1	32.9	CL
C	37.3	2.2	5.2	3.7	9.7	8.3	14.2	21.4	4.8	30.5	CL
Mulkey											
A11	27.3	2.1	8.1	6.2	14.6	14.2	19.6	15.6	2.4	17.2	L
A12	14.7	1.6	8.0	6.3	14.6	15.4	19.2	16.2	2.3	16.4	L
Quillayute											
A11	30.2	3.8	3.7	2.0	5.2	8.7	21.0	16.4	6.2	33.0	CL
A12	9.4	1.6	2.0	1.6	5.0	9.4	23.2	17.5	5.6	34.0	CL
A13	6.9	0.9	1.6	1.4	4.5	9.8	23.9	17.8	5.5	34.6	CL

APPENDIX III

Table 3. Mineralogical composition of the fine and very fine sand and coarse silt grains of the soil samples.

Table 3a. Key to abbreviations for mineral and other grains in mineralogical composition tables.

1. Glass - Volcanic glass.

2. Alt. - Altered, weathered, or severely abraded rocks, minerals or mineraloids unidentifiable with the petrographic microscope

3. Amph. - Amphibole

4. Aug. - Augite

5. Carb. - Carbonaceous material (charcoal and/or mineralized charcoal)

6. Cl.Stn. - Claystone

7. C.Pyr. - Clinopyroxene

8. Amyg. - Amygdule

9. Fld. - Feldspar

10. Gar. - Garnet

11. Hem. - Hematite

12. Hyp. - Hypersthene

13. Ilm. - Ilmenite

14. Mag. - Magnetite

15. Pl.Op. - Plant Opal

16. Qtz. - Quartz

17. Sph. - Sphene

18. Zeol. - Zeolite

19. Zir. - Zircon

Table 3b. Mineralogical composition[1]/ of the fine sand, very fine sand, and coarse silt fractions of the Price Peak soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Zeol.	Pl.Op.	Carb.	Alt.
A12	F.S.	6.6	88	13.3	--	4.7	--	0.7	1.1	4.2	76.0
	V.F.S.	6.2	77	12.0	--	6.2	--	2.4	5.2	2.6	71.6
	C.Si.	17.2	85	23.6	1.2	7.0	3.0	9.9	7.1	0.7	47.5
B21	F.S.	6.2	89	7.8	--	3.0	--	3.0	--	4.3	81.9
	V.F.S.	6.4	79	16.4	1.6	3.4	0.6	1.9	2.8	2.1	71.2
	C.Si.	16.6	88	30.8	2.4	6.2	2.1	7.8	3.1	2.6	45.0
B22	F.S.	7.3	91	8.2	0.9	2.7	--	2.4	--	3.3	82.2
	V.F.S.	6.8	88	12.5	1.9	2.1	0.4	3.7	2.1	2.8	74.5
	C.Si.	16.6	93	19.2	3.3	4.7	5.1	13.0	2.9	1.2	50.6

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %							
			Mag.	Aug.	Hyp.	Amph.	Mica	Hem.	Zir.	Alt.
A12	F.S.	12	13	2	58	11	4	--	5	--	22
	V.F.S.	23	7	2	56	7	2	--	4	1	18
	C.Si.	24	13	3	57	14	10	3	3	4	6
B21	F.S.	11	18	1	55	14	10	--	12	--	18
	V.F.S.	21	8	1	55	16	9	1	6	1	11
	C.Si.	12	13	4	60	12	6	4	2	2	8
B22	F.S.	9	26	1	62	17	13	--	3	--	14
	V.F.S.	12	10	1	56	15	16	1	2	1	8
	C.Si.	7	14	5	54	13	18	8	1	1	10

[1]/The key to mineral and other abbreviations is given in Table 3a.

Table 3c. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Yaquina Head soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %								
				Fld.	Qtz.	Glass	Pal.	Mica	Zeol.	Amyg.	Pl.Op.	Alt.
A11	F.S.	26.2	94	15.3	45.7	1.3	5.3	--	0.6	1.0	--	30.8
	V.F.S.	6.3	91	8.7	22.3	3.2	8.3	2.1	7.4	0.9	1.2	45.9
	C.Si.	5.4	95	7.3	24.5	1.6	4.3	4.6	13.2	0.3	3.8	41.4
IIA12	F.S.	13.3	91	3.7	22.4	2.3	9.1	--	5.7	3.1	--	53.7
	V.F.S.	7.4	91	7.4	20.8	4.2	7.8	1.8	12.0	4.4	0.5	41.4
	C.Si.	9.4	95	5.2	26.7	2.3	4.0	3.1	14.6	1.2	9.4	33.5
IIAC	F.S.	13.2	94	6.2	20.9	2.9	7.2	--	9.8	2.1	--	51.9
	V.F.S.	7.5	94	8.1	15.8	5.0	12.1	--	7.4	6.4	--	44.2
	C.Si.	9.4	97	4.6	29.1	1.4	8.0	1.1	6.8	1.4	2.1	45.5
IIC	F.S.	11.5	95	4.5	16.0	1.6	11.8	--	4.4	3.3	--	58.4
	V.F.S.	7.4	95	5.2	8.4	3.4	13.4	--	5.3	5.9	--	57.4
	C.Si.	9.5	97	6.9	27.3	2.2	6.0	1.4	7.7	2.1	1.8	44.4

Horizon	Separate	Wt.-%	Mag.	Heavy Fraction Count - %								
				Mag.	C.Pyr.	Hyp.	Amph.	Mica	Gar.	Zir.	Hem.	Alt.
A11	F.S.	6	5	27	27	11	18	--	5	3	--	9
	V.F.S.	9	8	33	22	6	10	--	2	2	--	17
	C.Si.	5	7	21	31	8	25	--	2	9	--	4
IIA12	F.S.	9	7	18	25	14	10	--	11	4	--	11
	V.F.S.	9	10	21	36	10	16	--	1	2	--	8
	C.Si.	5	12	14	28	13	22	2	1	5	1	4
IIAC	F.S.	6	8	32	17	11	15	--	9	2	--	14
	V.F.S.	6	10	23	21	23	11	--	2	3	--	17
	C.Si.	3	8	18	26	14	18	6	1	3	1	13
IIC	F.S.	5	7	21	21	9	16	--	3	1	--	29
	V.F.S.	5	14	14	12	29	23	1	1	3	--	17
	C.Si.	3	4	2	9	21	35	4	--	6	1	22

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3d. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Perpetua Head soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Zeol.	Conc.	Pl.Op.	Carb.	Alt.
A12	F.S.	11.0	74	43.9	0.7	0.5	2.7	1.0	0.3	0.5	50.4
	V.F.S.	8.6	78	34.6	2.2	1.2	4.8	1.3	2.2	0.6	52.3
	C.Si.	15.3	74	19.4	2.9	3.6	15.7	0.9	21.7	--	35.8
A13	F.S.	10.2	76	42.4	4.8	0.3	4.8	1.3	0.4	0.4	45.6
	V.F.S.	8.9	75	36.4	2.0	1.0	6.7	2.4	1.6	0.4	49.5
	C.Si.	15.9	74	23.2	2.5	2.1	10.5	2.1	21.1	--	38.5
C1	F.S.	9.7	77	38.1	1.2	--	3.5	1.2	0.4	0.8	54.8
	V.F.S.	8.3	75	31.3	2.1	0.9	2.9	2.2	0.8	--	60.0
	C.Si.	14.2	74	20.3	2.8	2.2	7.8	0.5	10.4	--	46.0

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %								
			Mag.	Aug.	Hyp.	Amph.	Mica	Gar.	Zir.	Hem.	Alt.
A12	F.S.	26	16	7	59	8	9	--	1	2	1	19
	V.F.S.	22	19	9	55	6	7	--	1	1	2	24
	C.Si.	26	22	4	47	4	3	1	--	1	2	42
A13	F.S.	24	17	9	55	6	4	--	2	1	--	23
	V.F.S.	25	18	6	54	3	6	--	1	1	--	29
	C.Si.	26	21	5	35	2	8	1	--	1	2	46
C1	F.S.	23	16	4	58	4	6	--	2	3	1	22
	V.F.S.	25	21	8	46	5	3	--	--	1	1	36
	C.Si.	26	22	6	46	1	4	1	--	1	3	38

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3e. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Perpetua Beach soil samples.

Horizon	Separate	Separate (Wt.)	Fraction (Wt.)	Light Fraction Count - %						
				Fld.	Qtz.	Glass	Zeol.	Pl.Op.	Carb.	Alt.
		%	%							
A12	F.S.	17.1	92	35.4	9.7	--	2.9	--	1.7	50.3
	V.F.S.	8.2	84	41.0	3.2	0.9	5.8	--	1.6	47.8
	C.Si.	14.7	93	42.7	8.8	1.3	7.1	2.4	--	37.7
B2	F.S.	14.8	87	37.8	8.5	--	4.0	--	1.5	48.2
	V.F.S.	10.6	87	26.7	8.7	0.7	4.4	--	0.5	59.0
	C.Si.	10.3	94	36.5	9.9	0.6	6.2	3.1	--	43.7

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %								
			Mag.	Aug.	Hyp.	Amph.	Mica	Hem.	Zir.	Gar.	Alt.
A12	F.S.	8	4	4	34	14	22	--	6	1	3	16
	V.F.S.	16	9	11	35	11	9	1	4	2	4	23
	C.Si.	7	10	10	31	7	12	1	6	2	--	31
B2	F.S.	13	5	3	40	16	12	--	5	1	5	18
	V.F.S.	13	8	8	34	19	8	1	6	1	2	21
	C.Si.	6	9	11	32	15	10	--	3	2	1	26

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3f. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Hembre series soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Conc.	Pl.Op.	Carb.	Alt.
A1	F.S.	5.3	97	11.3	--	1.6	0.3	7.8	0.3	3.3	75.4
	V.F.S.	8.3	96	15.6	2.3	2.8	1.2	13.9	1.7	1.9	60.3
	C.Si.	14.1	97	29.9	7.5	1.5	4.2	9.6	2.6	1.2	43.5
A3	F.S.	5.1	97	9.5	0.9	1.0	1.3	6.6	0.6	2.9	77.2
	V.F.S.	8.2	96	17.0	1.5	3.2	2.2	12.7	2.5	1.5	59.4
	C.Si.	14.5	97	27.3	5.8	0.8	3.5	11.4	1.9	0.7	48.6
B21	F.S.	10.5	98	8.4	--	0.3	--	8.6	--	1.8	80.9
	V.F.S.	8.4	97	13.6	3.7	3.5	1.9	15.4	1.9	1.5	58.5
	C.Si.	14.9	97	30.2	8.1	0.6	2.7	8.7	1.2	0.5	48.0

Horizon	Separate	Wt.-% Mag.	Ilm.-Mag.	Aug.	Hyp.	Heavy Fraction Count - %	Mica	Hem.	Zir.	Alt.
						Amph.				
A1	F.S.	3	24	8	7	19	12	--	23	--	31
	V.F.S.	4	20	6	15	13	11	7	18	1	26
	C.Si.	3	10	9	9	14	13	9	6	1	39
A3	F.S.	3	22	9	5	15	11	--	39	--	30
	V.F.S.	4	20	10	10	17	16	3	15	--	29
	C.Si.	3	15	15	3	11	13	5	11	2	40
B21	F.S.	2	33	9	9	26	14	1	21	--	20
	V.F.S.	3	11	22	8	14	19	6	4	--	18
	C.Si.	3	15	22	5	17	21	4	3	2	26

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3g. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Cascade Head soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %						
				Fld.	Qtz.	Glass	Pal.	Pl.Op.	Carb.	Alt.
A11	F.S.	2.7	88	5.7	2.4	0.6	0.3	--	0.3	90.7
	V.F.S.	5.6	84	3.6	3.2	1.5	2.2	--	0.7	88.8
	C.Si.	12.6	54	4.4	4.3	1.2	1.5	0.4	0.2	88.0
A12	F.S.	3.1	87	7.1	2.9	0.3	1.8	--	0.1	87.8
	V.F.S.	6.0	81	5.7	1.1	0.8	3.1	--	--	89.3
	C.Si.	16.4	47	4.8	2.4	1.0	0.5	0.2	--	91.1

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %								
			Mag.	Aug.	Hyp.	Amph.	Mica	Hem.	Zir.	Gar.	Alt.
A11	F.S.	12	39	13	30	3	10	--	4	--	3	37
	V.F.S.	16	52	10	43	9	8	--	3	1	--	26
	C.Si.	36	36	15	38	4	9	1	5	--	--	28
A12	F.S.	13	32	13	36	7	5	--	5	--	4	30
	V.F.S.	19	52	9	40	11	7	--	4	--	1	28
	C.Si.	53	37	12	34	3	10	--	8	--	--	33

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3h. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Tillamook Head soil samples.

Horizon	Separate	Separate (Wt.)	Fraction (Wt.)	Light Fraction Count - %						
				Fld.	Qtz.	Glass	Mica	Pl.Op.	Carb.	Alt.
		%	%							
A(CT-4)	F.S.	1.9	89	32.1	30.8	2.3	0.9	--	2.4	31.5
	V.F.S.	2.6	85	34.4	33.1	5.4	2.8	--	1.8	27.5
	C.Si	7.2	95	30.8	39.6	1.6	1.4	0.5	--	25.8
A(CT-5)	F.S.	2.7	83	33.9	28.8	4.3	1.6	0.2	1.3	29.6
	V.F.S.	3.4	76	24.1	28.3	6.1	3.9	--	1.6	36.0
	C.Si.	10.0	65	32.4	38.3	2.5	1.8	0.3	--	24.7

Horizon	Separate	Wt.-% Mag.	Mag.- Ilm.	C.Pyr.	Heavy Fraction Count - %						
					Hyp.	Amph.	Mica	Gar.	Zir.	Hem.	Alt.
A(CT-4)	F.S.	11	5	9	25	7	11	--	1	--	11	36
	V.F.S.	15	5	7	11	10	8	--	--	--	3	61
	C.Si.	5	7	15	9	25	26	1	--	1	2	11
A(CT-5)	F.S.	17	10	10	10	8	7	1	--	--	20	44
	V.F.S.	14	13	13	17	10	13	2	--	--	7	38
	C.Si.	35	14	20	18	11	24	3	--	1	4	19

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3i. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Mulkey series soil samples.

Hor-izon	Sepa-rate	Separate (Wt.) %	Frac-tion (Wt.) %	Light Fraction Count - %						
				Fld.	Qtz.	Glass	Mica	Pl.Op.	Carb.	Alt.
A11	F.S.	14.6	37	48.5	17.9	1.3	9.9	0.3	1.6	21.5
	V.F.S.	14.2	65	57.6	14.5	1.7	12.3	1.2	0.3	12.4
	C.Si.	19.6	83	51.9	15.1	0.9	19.6	1.6	--	10.9
A12	F.S.	14.6	36	43.2	20.3	0.9	11.1	--	0.9	23.6
	V.F.S.	15.4	67	49.2	16.1	2.1	14.8	0.4	1.2	16.1
	C.Si.	19.2	88	45.3	14.2	1.4	23.7	1.2	--	14.2

Hor-izon	Sepa-rate	Wt.-% Mag.	Mag.-Ilm.	Aug.	Heavy Fraction Count - %					
					Hyp.	Amph.	Ap.	Mica	Zir.	Alt.
A11	F.S.	63	2	29	12	1	36	6	7	--	9
	V.F.S.	35	2	25	17	2	39	4	8	1	4
	C.Si.	17	2	17	15	--	34	12	20	2	--
A12	F.S.	64	2	27	14	2	39	3	10	--	5
	V.F.S.	33	3	24	15	1	43	5	6	--	6
	C.Si.	12	3	14	13	--	36	10	24	1	2

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3j. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Quillayute series soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Pl.Op.	Amyg.	Carb.	Alt.
A11	F.S.	5.2	76	27.5	10.1	1.2	1.7	--	1.2	1.7	56.6
	V.F.S.	8.7	83	28.7	10.4	2.0	3.6	0.4	1.6	1.5	51.8
	C.Si.	21.0	90	37.9	15.2	1.0	9.8	3.1	0.5	2.3	30.2
A12	F.S.	5.0	77	25.2	9.8	1.2	1.6	--	1.2	2.2	58.8
	V.F.S.	9.4	83	23.6	10.6	1.7	2.6	1.3	0.9	1.1	58.2
	C.Si.	23.3	89	35.2	17.2	0.8	6.7	2.7	0.7	1.5	35.2
A13	F.S.	4.5	78	23.3	5.9	0.6	0.9	--	0.3	2.6	66.4
	V.F.S.	9.8	83	30.4	12.3	1.1	1.8	0.2	0.5	2.0	51.7
	C.Si.	23.9	85	30.5	18.6	0.9	5.5	3.3	0.3	2.5	28.4

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %							
			Mag.-Ilm.	C.Pyr.	Hyp.	Amph.	Mica	Hem.	Zir.	Alt.
A11	F.S.	24	15	6	70	3	7	--	1	--	13
	V.F.S.	17	16	13	57	9	11	--	1	--	9
	C.Si.	10	15	22	54	5	8	4	--	1	6
A12	F.S.	23	13	4	65	5	9	--	1	--	16
	V.F.S.	17	17	10	54	10	14	--	1	--	11
	C.Si.	11	16	19	48	9	12	2	--	2	8
A13	F.S.	22	15	8	74	6	9	--	2	--	11
	V.F.S.	17	16	9	58	8	13	--	2	--	10
	C.Si.	15	16	24	45	6	12	3	--	3	7

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3k. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Camas Prairie soil samples.

Horizon	Separate	Separate (Wt.) %	Fraction (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Zeol.	Pl.Op.	Carb.	C. Stn.
A	F.S.	1.2	91	47.3	30.4	3.5	0.7	0.7	--	1.2	16.2
	V.F.S.	2.6	93	48.3	27.2	1.1	2.6	1.3	0.5	0.8	18.2
	C.Si.	6.3	97	44.8	36.4	2.6	4.2	1.4	3.2	0.2	7.2
C	F.S.	1.6	94	41.5	25.4	0.8	0.3	--	--	0.4	31.6
	V.F.S.	2.7	96	33.7	23.8	1.5	3.2	0.8	--	0.6	36.4
	C.Si.	3.4	98	36.8	34.6	1.7	5.1	1.3	0.2	0.7	19.6

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %								
			Mag.	C. Pyr.	Hyp.	Amph.	Mica	Zir.	Sph.	Hem.	Alt.
A	F.S.	9	21	28	25	18	12	3	1	--	4	9
	V.F.S.	7	10	23	21	19	14	5	--	--	3	15
	C.Si.	3	7	34	12	17	13	2	4	--	1	17
C	F.S.	6	13	36	29	9	7	5	1	--	1	12
	V.F.S.	7	8	24	11	15	31	7	2	--	1	7
	C.Si.	2	5	32	13	7	17	1	5	--	1	23

1/The key to mineral and other abbreviations is given in Table 3a.

Table 31. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Camas Ridge soil samples.

Horizon	Separate	Separate (Wt.)	Fraction (Wt.)	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Zeol.	Pl.Op.	Carb	C.Stn.
		%	%								
A11	F.S.	2.3	97	14.2	9.8	0.9	--	1.2	0.2	2.3	72.4
	V.F.S.	3.4	97	13.3	14.7	2.4	1.9	2.3	1.1	1.6	62.7
	C.Si.	3.2	96	44.8	27.3	3.1	3.7	1.9	1.5	0.3	16.4
A12	F.S.	1.0	97	16.9	14.2	--	0.3	0.6	--	0.9	68.1
	V.F.S.	3.2	97	15.4	14.3	2.2	0.9	0.3	1.6	2.2	63.1
	C.Si.	7.8	96	29.7	26.1	4.5	4.8	1.7	2.2	0.5	31.5

Horizon	Separate	Wt.-% Mag.	Heavy Fraction Count - %								
			Mag.	C.Pyr.	Hyp.	Amph.	Mica	Zir.	Sph.	Hem.	Alt.
A11	F.S.	3	25	9	7	23	12	4	--	--	18	27
	V.F.S.	3	6	5	4	12	25	2	--	--	17	31
	C.Si.	4	4	24	8	17	25	1	2	1	5	16
A12	F.S.	3	10	17	4	17	7	1	1	--	22	31
	V.F.S.	3	9	15	6	14	17	1	1	--	12	32
	C.Si.	4	9	17	6	21	29	--	3	1	4	18

1/The key to mineral and other abbreviations is given in Table 3a.

Table 3m. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Molock Beach soil samples.

Hor-izon	Sepa-rate	Sepa-rate (Wt.) %	Frac-tion (Wt.) %	Light Fraction Count - %							
				Fld.	Qtz.	Glass	Mica	Zeol.	Pl.Op.	Carb.	Alt.
A1	F.S.	11.6	95	28.2	58.8	0.3	--	0.6	--	0.9	11.2
	V.F.S.	9.5	93	34.2	43.2	0.7	0.9	0.9	0.3	1.2	18.6
	C.Si.	12.6	96	37.5	42.8	1.2	3.1	--	1.1	--	14.3
AC	F.S.	11.3	97	28.5	53.7	--	--	--	--	1.3	16.5
	V.F.S.	8.1	93	31.4	44.2	0.6	0.3	--	--	0.9	22.6
	C.Si.	15.4	97	42.4	37.1	2.1	3.3	1.4	0.7	0.3	12.7
C	F.S.	9.3	96	25.8	64.4	--	0.8	--	--	0.3	8.7
	V.F.S.	9.1	93	46.0	40.0	0.4	--	--	--	--	13.6
	C.Si.	10.4	94	44.7	33.3	1.0	2.2	--	--	1.1	17.7

Hor-izon	Sepa-rate	Wt.-% Mag.	Ilm.-Mag.	Heavy Fraction Count - %								
				C.Pyr.	Hyp.	Amph.	Mica	Gar.	Zir.	Hem.	Oth. 2/	Alt.
A1	F.S.	5	3	24	7	8	16	--	14	3	3	5	20
	V.F.S.	7	5	18	15	13	30	1	3	6	2	3	9
	C.Si.	4	7	21	8	12	33	1	3	5	1	5	11
AC	F.S.	3	4	29	8	6	11	--	14	3	3	4	22
	V.F.S.	7	3	23	10	6	37	1	5	2	1	2	13
	C.Si.	3	5	27	8	4	31	1	3	4	--	4	18
C	F.S.	4	4	36	11	7	16	--	9	1	1	3	16
	V.F.S.	7	5	19	19	4	41	--	4	2	1	3	7
	C.Si.	6	7	29	10	7	28	2	1	3	--	6	14

1/The key to mineral and other abbreviations is given in Table 3a.

2/Others: kyanite, staurolite, epidote, clinozoisite, and possibly idocrase.

Table 3n. Mineralogical composition 1/ of the fine sand, very fine sand, and coarse silt fractions of the Molock Creek soil samples.

Horizon	Separate	Separate (Wt.)	Fraction (Wt.)	Light Fraction Count - %						
				Fld.	Qtz.	Glass	Mica	Pl.Op.	Carb	Alt.
		%	%							
A1	F.S.	12.5	96	51.5	36.1	0.9	0.2	--	2.1	9.2
	V.F.S.	17.0	94	49.7	30.9	3.4	0.6	0.8	1.3	13.3
	C.Si.	10.8	95	34.4	41.0	2.5	3.3	1.2	0.4	17.2
AC	F.S.	8.4	97	50.0	33.5	0.3	0.5	--	1.0	14.7
	V.F.S.	12.1	93	43.2	36.2	0.2	0.3	--	1.5	18.6
	C.Si.	12.8	96	39.1	39.8	1.7	2.8	0.3	0.9	15.4

		Wt.-% Mag.	Ilm.-Mag.	C.Pyr.	Hyp.	Heavy Fraction Count - %						
						Amph.	Mica	Gar.	Zir.	Hem.	Oth.2/	Alt.
A1	F.S.	4	4	12	9	17	35	--	3	1	1	4	18
	V.F.S.	6	6	7	14	11	40	--	2	3	--	10	13
	C.Si.	5	5	13	17	7	26	1	--	4	--	16	16
AC	F.S.	3	3	10	12	21	33	--	2	1	1	6	14
	V.F.S.	7	4	8	19	6	42	--	2	2	1	8	12
	C.Si.	4	3	15	12	9	29	2	1	3	--	10	19

1/The key to mineral and other abbreviations is given in Table 3a.

2/Others: kyanite, staurolite, epidote, clinoziosite, and possibly idocrase.

APPENDIX IV

Table 4. Analyses of extracts from 0.5 N NaOH dissolution sequences on clay samples given Pretreatments I and II.

Soil and Horizon	Pretreatment I 1:1500, Clay/NaOH				Pretreatment II 1:1000, Clay/NaOH			
	Si	Al	Fe	Mg	Si	Al	Fe	Mg
	mmol/g sample				mmol/g sample			
Price Peak								
A12	2.49	2.73	0.16	0.04	2.27	1.44	0.09	0.03
B21	2.40	3.20	0.15	0.04	2.04	2.20	0.08	0.02
B22	2.38	3.43	0.14	0.04	2.25	2.40	0.08	0.02
Yaquina Head								
A11	2.47	2.78	0.32	0.05	2.43	1.84	0.11	0.03
IIA12	2.45	2.08	0.36	0.05	2.38	1.32	0.09	0.03
IIAC	2.38	2.87	0.30	0.04	2.06	1.92	0.09	0.03
IIC	2.31	3.01	0.21	0.03	2.17	2.40	0.08	0.02
Perpetua Head								
A12	3.03	3.15	0.21	0.05	2.85	1.71	0.09	0.04
A13	2.69	3.61	0.26	0.05	2.40	2.69	0.11	0.04
C	2.89	4.08	0.15	0.04	2.86	3.01	0.09	0.03
Perpetua Beach								
A12	2.38	3.57	0.20	0.03				
B2	2.40	3.73	0.20	0.04				
Hembre								
A1	1.89	3.43	0.29	0.05				
A3	1.78	3.52	0.28	0.05				
B21	1.60	3.98	0.25	0.04				
Cascade Head								
A11	2.31	2.41	0.28	0.05				
A12	2.29	2.74	0.27	0.04				
Tillamook Head (CT-4)								
A	1.39	1.30	0.10	0.02				
Tillamook Head (CT-5)								
A	2.03	2.29	0.26	0.05				

Table 4. continued

Soil and Horizon	Pretreatment I 1:1500, Clay/NaOH				Pretreatment II 1:1000, Clay/NaOH			
	Si	Al	Fe	Mg	Si	Al	Fe	Mg
	mmol/g sample				mmol/g sample			
Mulkey								
A11	1.65	1.58	0.23	0.03	1.46	0.92	0.12	0.03
A12	1.67	1.88	0.24	0.03	1.37	1.31	0.11	0.03
Quillayute								
A11	1.84	2.22	0.12	0.04	1.96	1.60	0.08	0.03
A12	1.76	2.43	0.14	0.05	1.74	1.66	0.07	0.03
A13	1.63	2.62	0.15	0.05	1.73	1.74	0.06	0.03
Camas Prairie								
A	1.56	1.10	0.07	0.03				
C	1.34	0.90	0.07	0.02				
Camas Ridge								
A11	1.33	0.97	0.07	0.03				
A12	1.25	0.88	0.06	0.03				
Molock Beach								
A1	1.40	1.70	0.10	0.03				
A12	1.60	2.97	0.08	0.03				
C	1.74	3.60	0.07	0.02				
Molock Creek								
A1	1.67	1.02	0.09	0.04				
AC	2.16	3.15	0.06	0.02				

APPENDIX V

Table 5. Cation exchange capacities of clay samples given Pretreatment I and moisture loss at 110° C after equilibration of the Ca-saturated samples at 54% relative humidity.

| Soil and Horizon	Cation Exchange Capacity	110° H_2O Loss	Soil and Horizon	Cation Exchange Capacity	110° H_2O Loss
	me/100 g	%		me/100 g	%
Price Peak			**Mulkey**		
A12	51	8.0	A11	46	6.3
B21	52	7.8	A12	43	6.3
B22	47	7.7			
			Quillayute		
Yaquina Head			A11	52	7.7
A11	54	9.2	A12	53	7.9
IIA12	63	8.3	A13	49	6.8
IIAC	50	7.4			
IIC	64	7.6	**Camas Prairie**		
			A	66	8.9
Perpetua Head			C	62	10.8
A12	72	11.3			
A13	102	13.9	**Camas Ridge**		
C	108	14.5	A11	68	9.5
			A12	59	9.5
Perpetua Beach					
A12	74	12.1	**Molock Beach**		
B2	68	12.1	A1	52	7.2
			AC	47	8.8
Hembre			C	69	8.0
A1	53	8.4			
A3	50	8.0	**Molock Creek**		
B21	40	7.4	A1	81	10.5
			AC	54	9.5
Cascade Head					
A11	51	7.8	**Gibbsite Nodule (78%)**		
A12	52	7.4		5	2.4
Tillamook Head (CT-4)			**Nontronite Standard**		
A	55	7.1			16.2
Tillamook Head (CT-5)					
A	54	7.7			

Figure la. X-ray diffraction patterns of crushed Na-saturated sands
from the Price Peak A12 and B22 horizons.
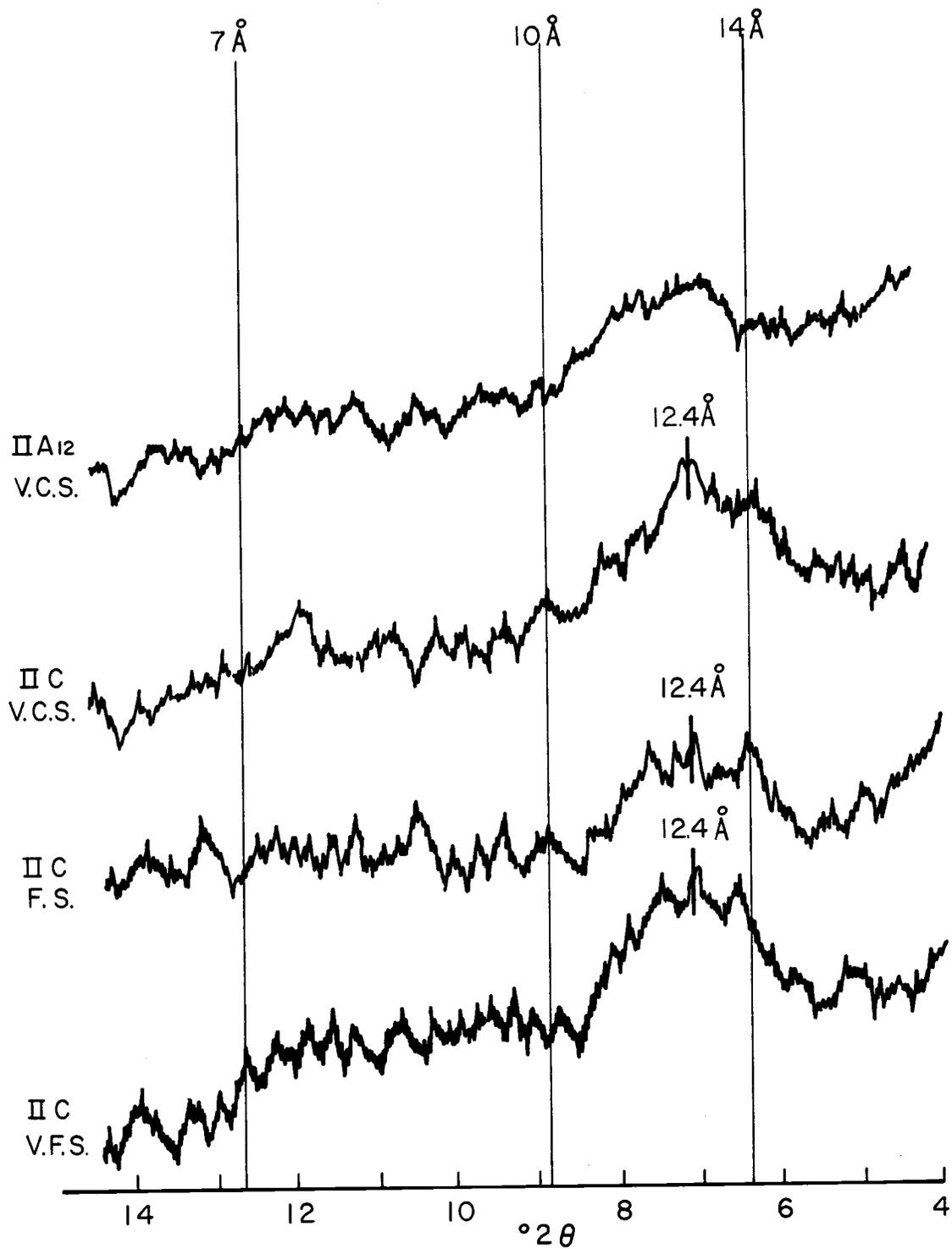
Figure 1b. X-ray diffraction patterns of crushed Na-saturated sands from the Yaquina Head IIA12 and IIC horizons.
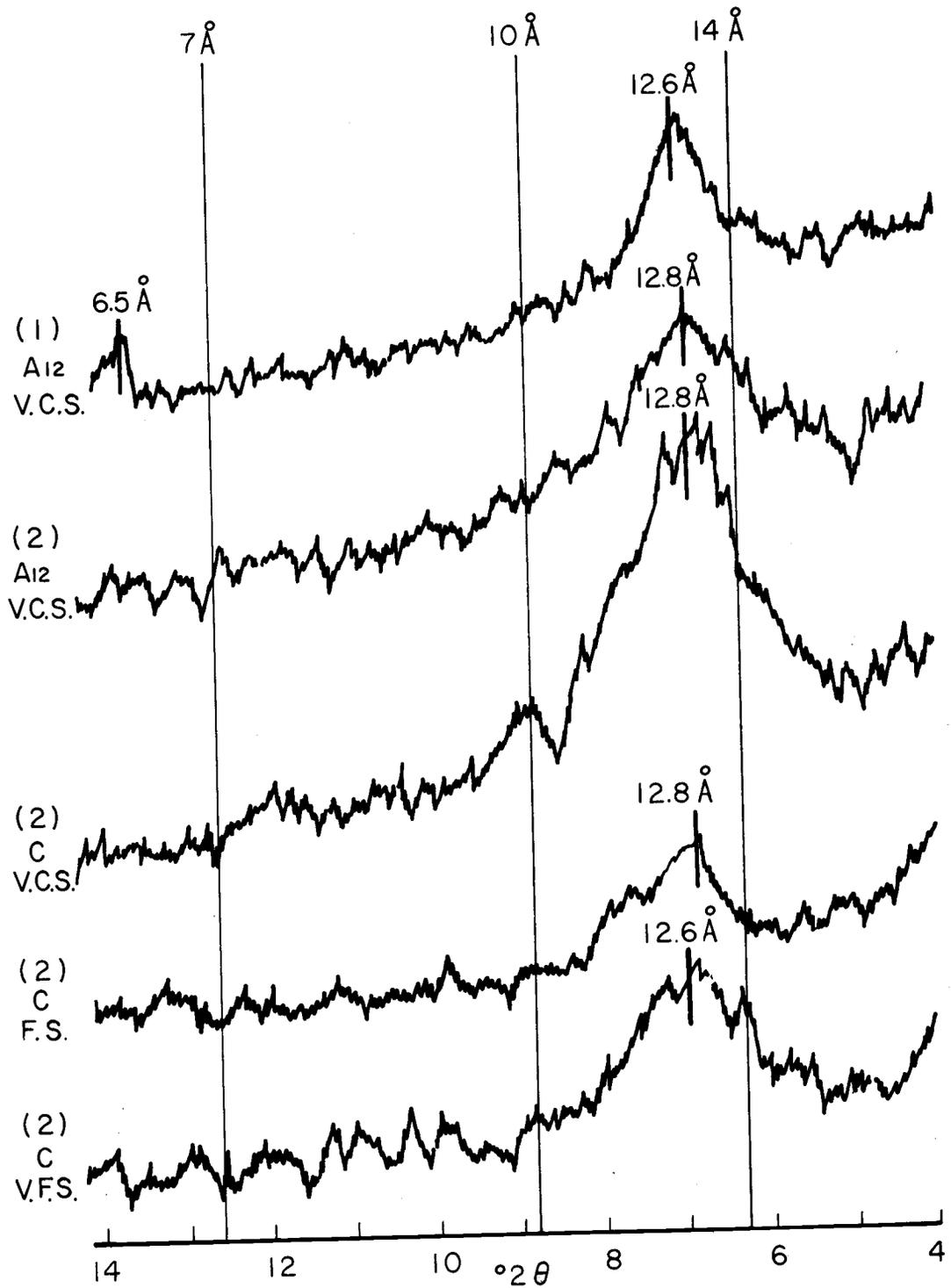
Figure 1c. X-ray diffraction patterns of crushed Na-saturated sands
from (1) Perpetua Beach A12; (2) Perpetua Head A12 and
C horizons.
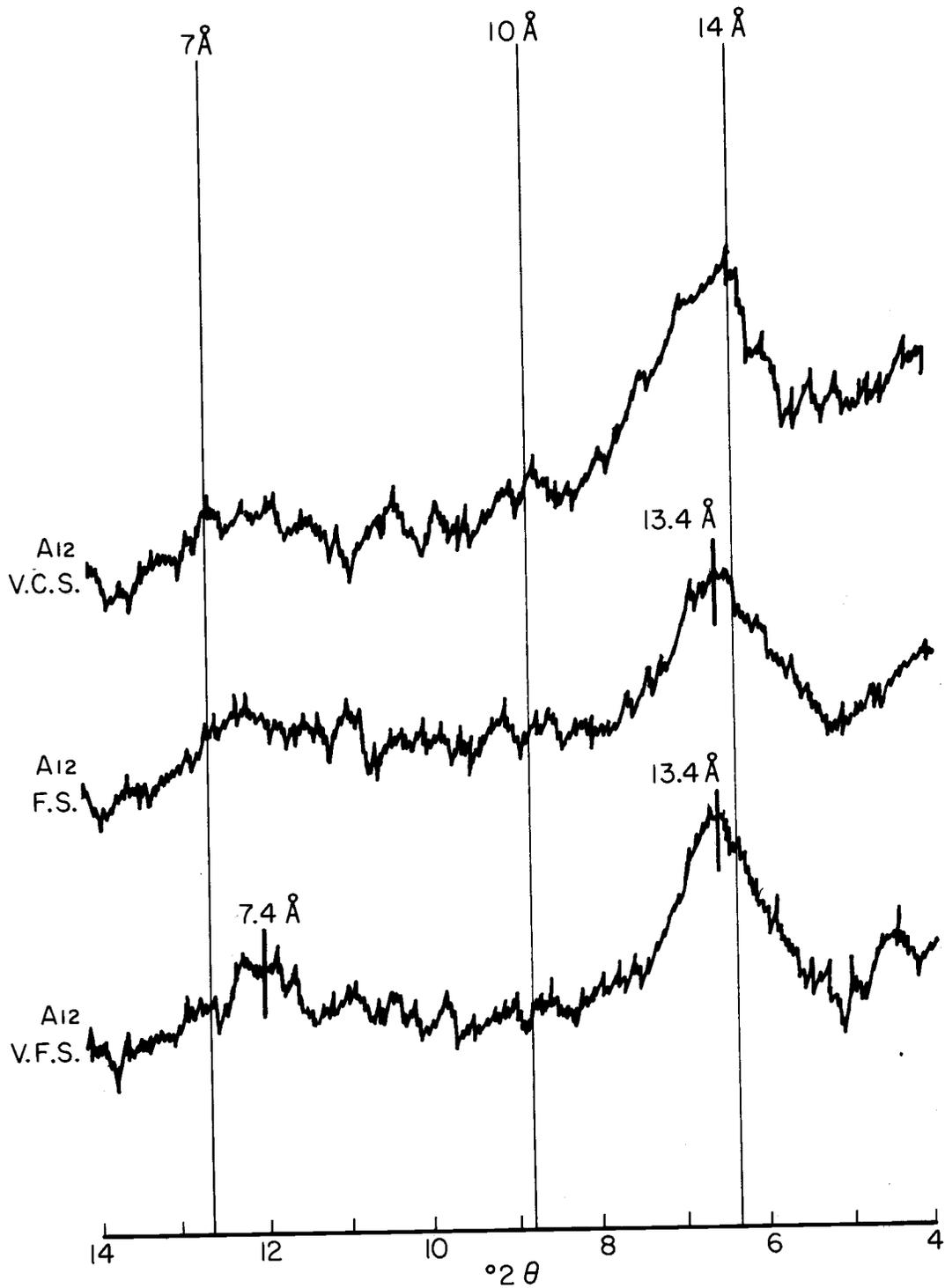
Figure 1d.   X-ray diffraction patterns of crushed Na-saturated sands
from the Cascade Head A12 horizon.
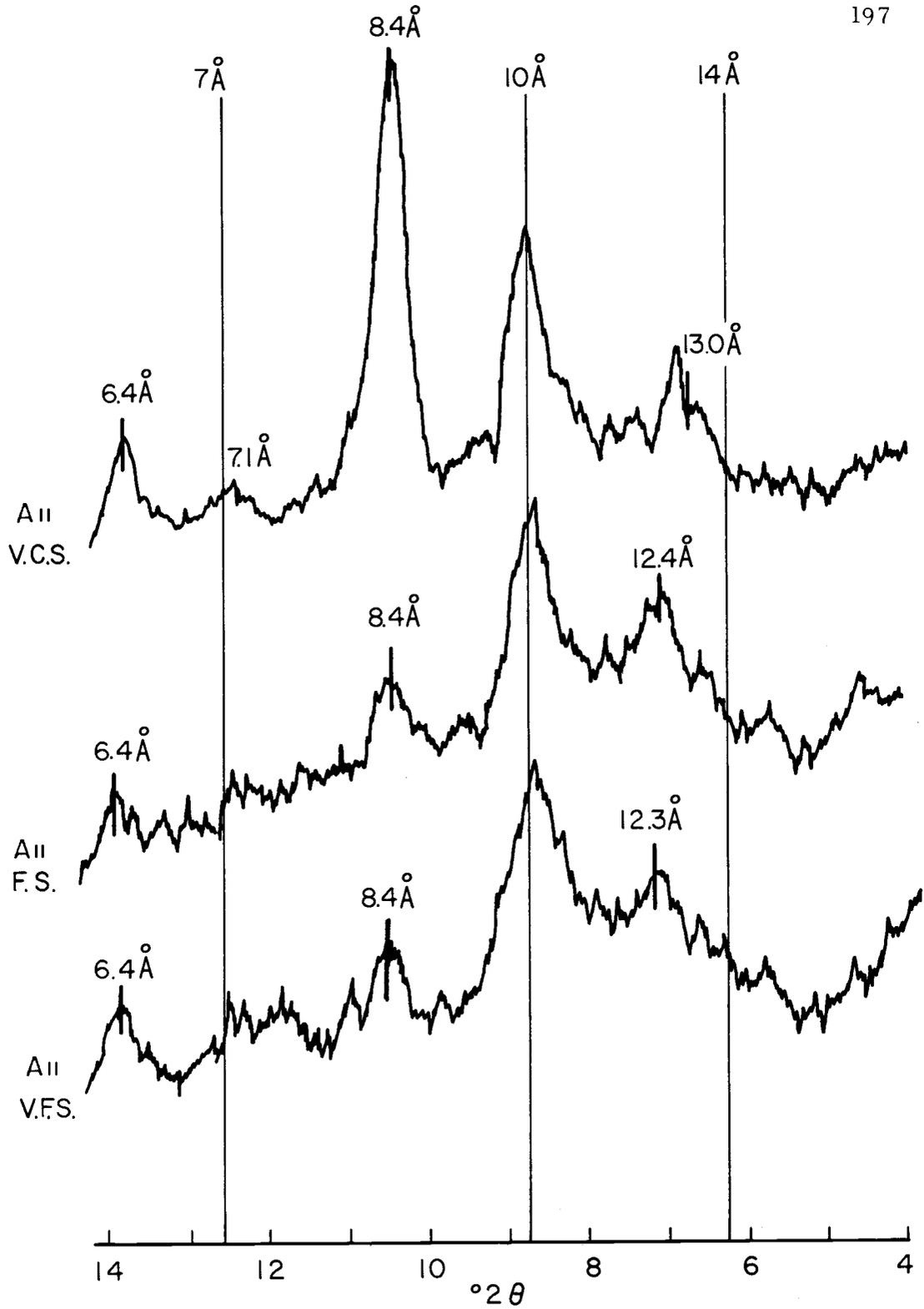
Figure 1e. X-ray diffraction patterns of crushed Na-saturated sands
from the Mulkey A11 horizon.
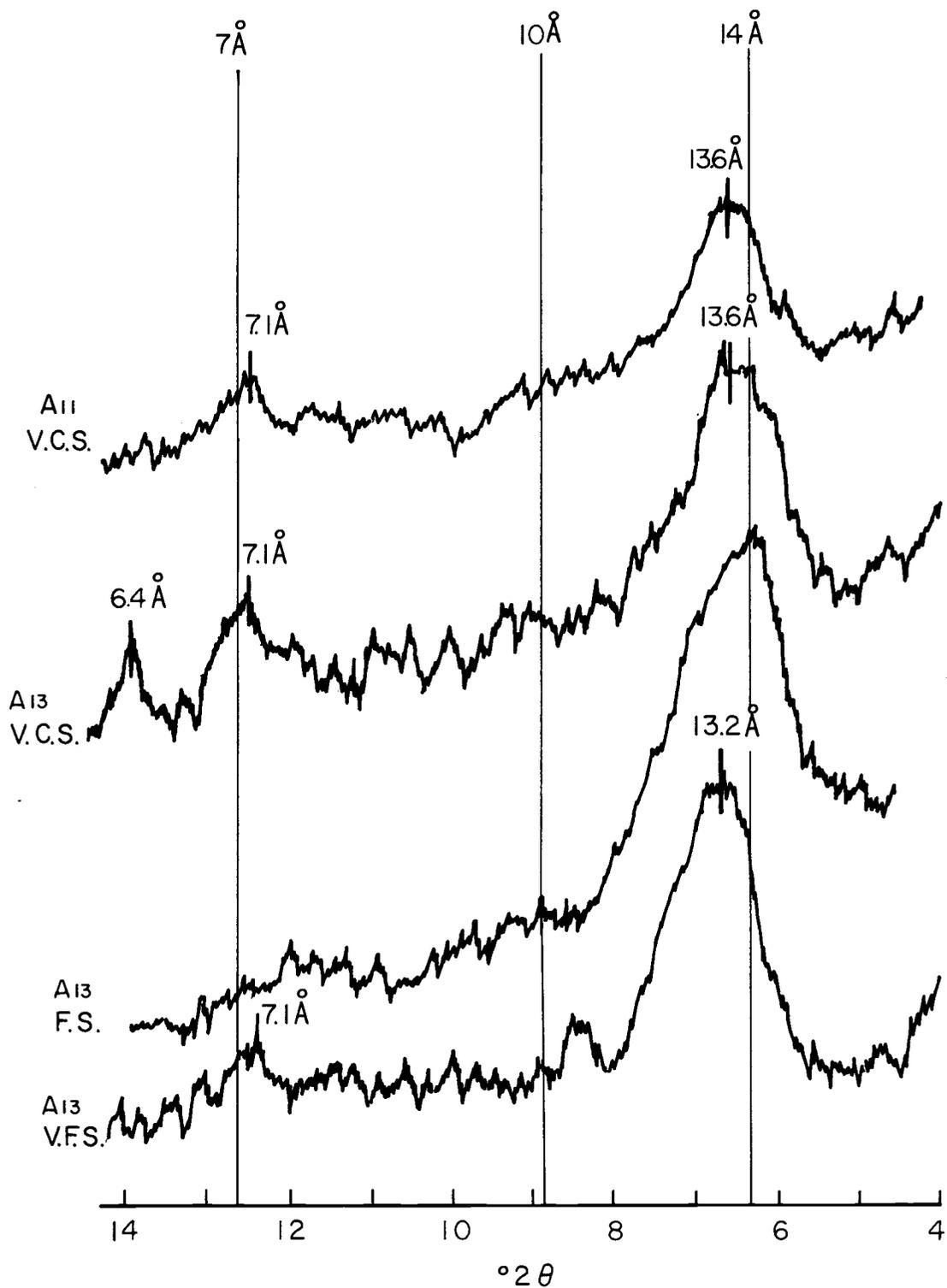
Figure 1f. X-ray diffraction patterns of crushed Na-saturated sands from the Quillayute A11 and A13 horizons.
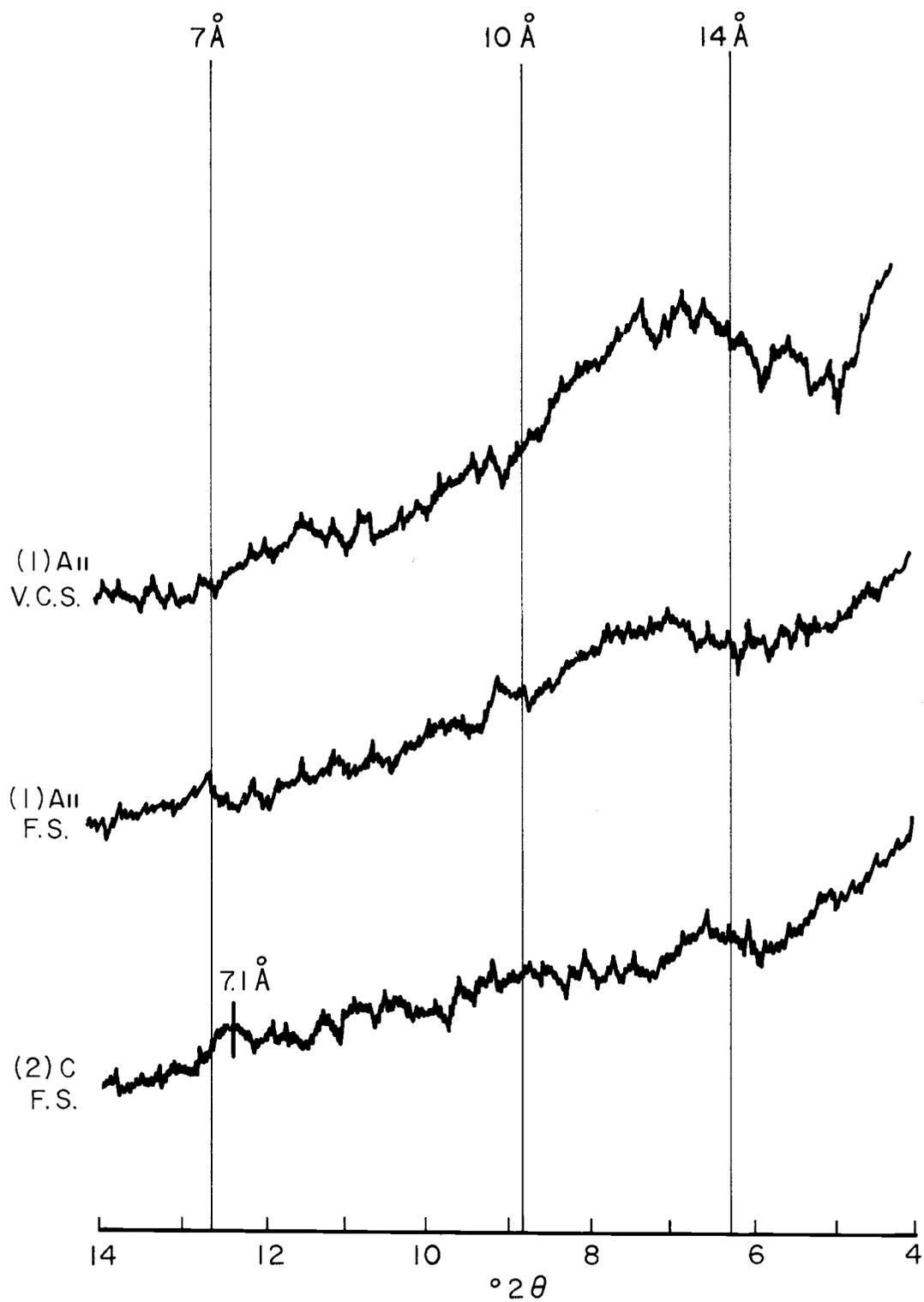
Figure 1g. X-ray diffraction patterns of crushed Na-saturated sands from: (1) Camas Ridge A11; (2) Molock Beach C horizons.